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**Synchronous haptic experience and self-other boundaries
in human computer interaction**

by

Norene Kelly

A thesis submitted to the graduate faculty
in partial fulfillment of the requirements for the degree of
MASTER OF SCIENCE

Major: Human Computer Interaction

Program of Study Committee:
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Ames, Iowa

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ABSTRACT

The boundaries of the self may be manipulated to incorporate objects in the physical sense (e.g., the rubber hand illusion) and other people in the conceptual sense (e.g., the enfacement effect). Synchronous stimulation has been used to manipulate both physical and conceptual self boundaries. Although the literature offers many discussions of the metaphoric overlap between self and other, experimental study of the embodied aspects of this phenomenon has been lacking. This study consequently manipulated multimodal stimulation to test factors potentially affecting self-other overlap in a user-actor human computer interaction (HCI). As HCI progresses from information design to experience design, from inelegant artifacts to ambient intelligence, an embodied perspective can inform the interaction of technology and the body, affect, and social cognition.

The independent variables in the experiment were: (1) the presence or absence of a haptic device (neck massager) on the participant; (2) the presentation of one of two videos, in which an actor expressed either energy or calmness while wearing the haptic device; and (3) the pre- and post-intervention time factor. The experiment measured the effect of these variables on the following dependent variables: (1) heart rate; (2) skin conductance; (3) energetic arousal; (4) calmness; and (5) interpersonal closeness to the actor.

The results showed a main effect for time for all dependent variables. Regardless of haptic device or video content, heart rate decreased, skin conductance increased, self-reported calmness increased, self-reported energetic arousal decreased, and self-reported interpersonal closeness to the actor increased. A three-way interaction effect was evident for the measures of calmness and interpersonal closeness. The greatest reported increase in calmness occurred in the haptic-energy video condition. The greatest reported increase in interpersonal closeness also

occurred in the haptic-energy video condition, an effect that was consistent with one of the study's hypotheses. HCI applications that incorporate both haptic and interpersonal closeness factors would be wise to consider this effect and subject it to further testing.

CHAPTER 1. INTRODUCTION

“Everywhere in the world, self starts with body” (Baumeister, 1999, p. 2). Indeed, to children (and to some adults depending on the culture) the self *is* the body (Baumeister, 1999). The skin-boundary surrounding the total organism is the most common boundary line that individuals imagine or accept as valid between “self” and “not self” (Wilber, 2001). However, the skin boundary line can and does shift (Stoytchev, 2009; Wilber, 2001). Our body representation is constantly updated starting from the integration of different sensory inputs (Holmes & Spence, 2004; Mazzurega, Pavani, Paladino, & Schubert, 2011).

Further evidence suggests that a definitive body/world boundary is artificial, and what one normally thinks of as one’s own body is more of a phantom created by the brain (Stoytchev, 2009). Stoytchev (p. 3) posits some reasons this would be so: our bodies are constantly changing, complicated events are continuously occurring within the body, and so “the composition of the body must be constructed continuously from the latest available information.”

However, the self is not only the body. When an adult in Western culture speaks about the self, she is most likely referring to not just her physical being, but also to her psychological being (e.g., thoughts, feelings, attitudes), which in turn exists within a social matrix (Baumeister, 1999). Some theories, for example social identity theory and self-categorization theory, propose that the self can be defined at different levels, ranging from sub-personal to personal to group levels (Schubert & Otten, 2002; Tajfel & Turner, 1979; Turner, Hogg, Oakes, Reicher, & Wetherell, 1987).

Conceptually, then, the self can be socially extended to other persons (Schubert & Otten, 2002). Wegner (1980) suggested that empathy may in part arise from a basic confusion between one’s self and others. Paladino, Mazzurega, Pavani, and Schubert (2010, p. 1202) pointed out

that “relationships with loved ones are often described as a blurring of self-other boundaries and by the metaphorical expressions ‘you are part of me’ and ‘we are one.’ Research shows that such merging can occur at the conceptual level and at the bodily level.”

Our conceptual sense of self, then, is bound to our physicality and hence influenced by the sensorimotor domain, and self-concept is influenced by bodily feedback (Lakoff & Johnson, 1999; Schubert & Koole, 2009). Lakoff and Johnson (1999, p. 555) put forth a “new view of the person” in which embodied reason means that: our conceptual system is grounded in, neurally makes use of, and is crucially shaped by our perceptual and motor systems; we can only form concepts through the body; and major forms of rational inference are instances of sensorimotor inference. Such an embodied realism rejects a strict subjective-objective dichotomy (Lakoff & Johnson, 1999).

With regard to self boundaries being mutable rather than concrete, Smith (2008, p. 149) noted this gap in research: “Despite the prominence in the literature of discussions of the metaphoric ‘overlap’ between self and other, theoretical analyses of its nature have been limited and incomplete.” He continued that the assumptions have been that this overlap is cognitive in nature, and that the embodied aspects have been generally ignored. Thus, this multidisciplinary thesis brings an embodied perspective to the study of self-other boundaries within the context of human computer interaction (HCI). The evolution of technology toward intelligent, adaptive systems that are capable of inferring emotion and incorporating multimodal interactions demands such research to offer a deeper understanding of the interplay of body and self, of emotion and social cognition.

The current study experimentally manipulated one sensorimotor modality (tactile) of participants, while participants viewed on a computer another person experiencing this haptic

event, to test the effect on self-other boundaries, as measured by change in psychophysiology, mood, and interpersonal perceptions. Specifically, each participant was assigned to one of four conditions consisting of three interacting factors. The first factor was either the presence or absence of a haptic device (i.e., neck massager) on the participant. The second factor was the presentation of one of two videos of an actor^{*} wearing the same haptic device; in one video the actor expressed energy, and in the other she expressed calmness. The third factor was time—participants' pre- and post-video heart rate, skin conductance, and self-reported measures of energetic arousal, calmness, and interpersonal closeness to the actor.

Hypothesis 1 was that the energy video would have an energizing effect (i.e., increase in heart rate and skin conductance; increase on energetic arousal measure) and the calm video would have a calming effect (i.e., decrease in heart rate and skin conductance; increase on calmness measure) in both the haptic and no haptic conditions. Further predicted was that in the haptic conditions, these effects would be greater. Hypothesis 2 was that participants in both the haptic-energy video and haptic-calm video conditions (as compared to those in the two no haptic conditions) would realize a pre-post gain on the interpersonal closeness measure.

In the coming sections, the literature review will first elucidate the theoretical and practical development of this experiment. Next, the experimental methods and procedures are addressed, followed by the results. Finally, the results and implications are discussed.

^{*} The gender-neutral term “actor” is used for the female who acted in the video.

CHAPTER 2. REVIEW OF LITERATURE

Presented first is an overview of the embodied perspective and its relation to the concept of self boundaries. Second is literature demonstrating that the physical self boundary can be manipulated via synchronous stimulation, followed by literature demonstrating that the conceptual self boundary can be manipulated via synchronous stimulation. Next addressed are self-object and self-other boundaries in human computer interaction. This is followed by a review of the measurement of (1) emotional contagion via change in mood and (2) self-other conceptual boundaries. Finally, the hypotheses of the study are presented.

The Embodied Perspective and Self Boundaries

An embodied perspective (e.g., Lakoff & Johnson, 1999; Marsh, Johnston, Richardson, & Schmidt, 2009) has guided the conceptualization and execution of this thesis. In the past few decades, this perspective has inspired research and new theoretical ideas in the cognitive and behavioral sciences (Semin & Smith, 2008). An embodied framework has at its core that nervous systems evolved for the adaptive control of action, not abstract cogitation, and that the object of study in psychology is the whole behaving organism in its natural context (Semin & Smith, 2008). Winkielman, Niedenthal, and Oberman (2009) reviewed numerous studies demonstrating that simple body-based manipulations, such as facial expression, posture, or movement, can causally influence the processing of emotional information. With regard to the social world as well, our cognitive representations are not amodal but fundamentally connected with actions that our bodies perform, and these actions consequently inform our concepts, language, and thinking (Semin & Smith, 2008; Winkielman et al., 2009).

Conversely, traditional models of information processing are symbolic, and knowledge is dissociated from sensory and motor bases (Semin & Cacioppo, 2008). Such traditional models

require a translation to take place between the symbolic representational system and the experienced event. In the embodied view, however, “social cognition is best understood as grounded in (rather than abstracted from) perceptuomotor processes and intertwined with a wealth of interpersonal interaction and specialized for a distinctive class of stimuli” (Semin & Cacioppo, 2008, p. 120). One distinctive class of stimuli is *other human beings and their bodily movements, which can be mapped onto our own bodies*. Thus, the embodied view hypothesizes that social cognition is not entirely driven by inner processes but “relies on resources that are distributed across neural, bodily, and environmental features” (Semin & Cacioppo, 2008, p. 121; see also Agre, 1997; Brooks, 1999; Hutchins, 1995; Kirsch, 1995).

Although detailing the variety of experimental literature that supports this embodied perspective is beyond the scope of this thesis, one example well illustrates the neurological underpinnings of bodily mappings between a nonhuman primate and another in a social context. In the F5 area of the premotor cortex of the macaque monkey, Rizzolatti, Fadiga, Gallese, and Fogassi (1996) identified a particular class of visuomotor neurons (termed *mirror neurons*) that discharged when the monkey engaged in a particular action (e.g., grasping a peanut) *and* when it observed another monkey engaging in the same action. Semin and Cacioppo (2008) stated that there is an emerging body of evidence that in humans as well there exists a system of neurons that synchronize to observed actions. This “neural parity” results in a shared neural state between self and other, and thus allows the other to become another or a part of “self,” or in other words blurs the boundary between self and other, evoking a state of empathy.

Although mirror neurons do not “produce” complex social-psychological phenomena such as empathy, “they do provide concrete cellular evidence for the shared representations of perception and action” (Preston & de Waal, 2002, p. 10). To describe and integrate the ultimate

and proximate bases of empathy, Preston and de Waal (2002, p. 4) put forth the perception-action model of empathy (“PAM”), which states that “attended perception of the object’s [other’s] state automatically activates the subject’s representations of the state, situation, and object, and that activation of these representations automatically primes or generates the associated autonomic and somatic responses, unless inhibited.” PAM is grounded in the theoretical idea, adopted by many fields over time, that perception and action share a common code of representation in the brain. Preston and de Waal (2002) stated that research with humans, nonhuman primates, and rodents support PAM for motor and emotional behavior, and suggest that at least across these species, the mechanisms for processing emotional stimuli are similar.

Preston and de Waal (2002, p. 14) pointed out that Hume, Freud, and other theorists have expressed the role of familiarity and similarity in facilitating empathy; “the greater the familiarity or similarity, the richer the subject’s representation of the object. A rich representation involves more associations, and thus, creates a more complex, elaborated, and accurate pattern of activity in the subject...” Similarity of physical appearance, demographic characteristics, and common experiences have been demonstrated to invoke empathy in humans (e.g., Batson, Duncan, Ackerman, Buckley, & Birch, 1981; Feshbach & Roe, 1968; Rosekrans, 1967; Toi & Batson, 1982).

In broader terms, the facilitation of empathy via similarity means that a human observing a primate moving a forelimb would more strongly activate a human’s representation than the sight of a rodent. Thus overlap of morphology and biomechanics is important, and comparative data have noted the need for stimuli to be naturalistic or multimodal to evoke a response (Preston & de Waal, 2002).

The identification of mirror neurons and the PAM theory in turn elucidate the concept of emotional contagion. Hatfield, Cacioppo, and Rapson (1993; 1994) described emotional contagion as a multiply-determined family of social, psychophysiological, and behavioral phenomena in which the automatically mimicked and synchronized facial expressions, vocalizations, postures, and movements of people results in emotional convergence. Just as emotion for the individual has an adaptive utility as well as drawbacks, the attentional, emotional, and behavioral synchrony of contagion has important consequences for social dyads and groups. Hatfield et al.'s text (1994) compiled studies and examples of emotional contagion, which is automatic, unintentional, uncontrollable, largely inaccessible to conversant awareness, and tightly linked to somatic expression.

Biocca (1997, p. 13) further illuminated the role of the body in emotional contagion, citing others' findings of the body as:

... an expressive communication device (Benthall & Polhemus, 1975), a social semiotic vehicle for representing mental states (e.g., emotions, observations, plans, etc.) to others. The body emits information to the senses of other bodies, whether intentional or not (Ekman, 1974). Observers of the physical or mediated body read the emotional states, intentions, and personality traits by an empathic simulation of them (Zillmann, 1991a). The body transmits information to other bodies through a kind of affective contagion.

This thesis is concerned with how an embodied perspective of social cognition can inform new directions in human computer interaction. Semin and Cacioppo (2008, p. 131) defined social cognition as “dynamic, unfolding processes that take place between two or more agents who are engaged in action and reaction, and the shape of this interaction takes a multitude

of forms ranging from a wide range of different nonverbal to verbal exchanges.” They further posited that social cognition is manifested in synchronization, coordination, and co-regulation of behaviors.

As previously described, one’s sense of self is both physical and conceptual. In an infant, the understanding of where one’s physical body begins and ends is developed via cross modal synchrony—that is, the matching of vision and muscle movements. This has implications for the development of the conceptual self as well; such cross-modal synchrony “... can lead to the inclusion of more than just individual in the self. If the infant sees that mother smiles when I smile or wince when I feel pain, then it is natural for the infant to think that mother is, in some very real way, a part of me. This line of reasoning suggests that interpersonal synchrony is a basic, automatic cue that the other person is part of the psychological self” (Smith, 2008, p. 152). In this way, the physical and conceptual senses of self are bound, and the self is bound socially to others. The next section discusses how manipulations in cross-modal synchrony can affect one’s perception of self-boundary—first in a physical sense, and second in a conceptual sense.

Manipulating the Physical Self Boundary with Synchronous Stimulation

The rubber hand illusion (RHI), an illusion of body schema, has been identified as a useful paradigm to investigate body ownership, self-identification, or self-other merging (Mazzurega, Pavani, Paladino, & Schubert, 2011) and arises because it is the best explanation of the sensory input (Hohwy & Paton, 2010). The RHI has provided compelling evidence that the cognitive representation of one’s body is flexible and continuously updated as a result of new multisensory inputs (Paladino, Mazzurega, Pavani, & Schubert, 2010). Thus, the RHI is informative for this study’s exploration of haptic input and self-boundaries.

When there is a mismatch among sensory stimulation (e.g., tactile versus visual information), an illusion can arise that blurs or confuses bodily boundaries. An illusion is the marked and often surprising discrepancy between a physical stimulus and its corresponding perception (Lederman & Jones, 2011). The RHI allows a fake limb to be made to feel as a part of one's own body when the normal association between touch and vision is disrupted (Slater, Spanlang, Sanchez-Vives, & Blanke, 2010). Once known as a “parlor trick,” the RHI has received increasing scientific scrutiny in the past decade for its applicability to areas as diverse as the phenomenology of the self, successful prosthesis use, the etiology of schizophrenia, and virtual environment applications (De Preester & Tsakiris, 2009; Ijsselstein & Hanns, 2008; Slater, Perez-Marcos, Ehrsson, & Sanchez-Vives, 2008; Thakkar, Nichols, McIntosh, & Park, 2011).

Botvinick and Cohen (1998) conducted a basic RHI experiment in which each of ten participants was seated with his or her left arm resting upon a table. This arm was hidden from the participant's view with a standing screen, and a life-like rubber left hand and arm was placed on the table in front of the participant. The participant sat with eyes fixed on the artificial hand while the researchers used two small paintbrushes to stroke the rubber hand and the participant's hidden hand synchronously.

After ten minutes, the participants completed questionnaires, indicating that they experienced the illusion—they sensed the touch on the rubber hand, which they felt as their own. Whereas this experiment recorded just self-reports, consequent experiments have documented physiological changes in the “absent” hand, for example as measured by galvanic skin response and temperature (Hagni, Eng, Hepp-Reymond, Holper, Keisker, Siekierka, & Kiper, 2008; Yuan & Steed, 2010).

Botvinick and Cohen's second experiment demonstrated a quantifiable behavioral correlate. The RHI was conducted over longer periods, and afterwards subjects were asked to close their eyes and align their right index finger with their left index finger. The researchers reported that "[s]ubjects' reaches after experiencing the illusion were displaced rightward toward the rubber hand, the magnitude of this displacement varying significantly in proportion to the reported duration of the illusion" (p. 756). This phenomenon has been labeled "proprioceptive drift" and has been replicated in a number of other experiments (e.g., Rohde, DiLuca, & Ernst, 2009; Tsakiris, Prabhu, & Haggard, 2006). Botvinick and Cohen concluded that the RHI shows "...that intermodal matching can be sufficient for self-attribution" (p. 756).

Hohwy and Paton (2010) explained that in the standard RHI, the sensory input to be explained comprises the touch produced with a visual stimulus, the visual input of the artificial rubber hand, and the proprioceptive incongruence between one's own hand and the viewed rubber hand. What happens then is that "...synchronous touch, which weighs in favour of projecting touch to the rubber hand, can dominate the other kinds of evidence, all of which weigh against projecting touch to the rubber hand" (Hohwy & Paton, 2010, p. 1).

Other studies have looked at the possibility of the illusion working on a doll or virtual body, rather than just a hand or limb (Hohwy & Paton, 2010). In an effort to integrate conflicting visuotactile stimuli, the illusion can overcome prior knowledge of the visual body-image, proprioception or self location, and general background knowledge. However, "the robustness, limits and further perceptual consequences of such illusions are not yet fully explored or understood" (Hohwy & Paton, 2010, p. 1).

The RHI and other tactile and body illusions have various implications for and applications in human computer interaction and virtual environments. Using lessons derived

from RHI experiments, developers can design tools so that they are better incorporated as part of one's body/self (e.g., laproscopic surgery tools, robotic arms) and thus function better. Another area is the development of avatars, games, and virtual worlds that make the user feel more bodily present in the mediated environment.

Additionally, it is possible to experience haptic illusions in the absence of any physical haptic stimulation (e.g., dynamic visualization of a physical force producing the feel of a virtual spring). Such cross-modal illusions represent a form of synesthesia that may enhance the user's experience of spatial and sensory presence in an immersive virtual environment (Lederman & Jones, 2011).

Slater, Perez-Marcos, Ehrsson, and Sanchez-Vives (2008) tested the RHI using a 3D stereo virtual arm projecting horizontally out of the subject's shoulder. They demonstrated that a virtual limb could be made to feel part of the subject's body with the use of appropriate multisensory correlations. Thus, their work suggested that:

... people can have their 'self' enter the virtual domain in a genuine sense of the word, and not just metaphorically as in current day computer games and online communities. In combination with BCI [brain-computer interface] we envisage a functioning virtual body that is felt as their own by participants, with significant applications in VR training, limb prosthetics, and entertainment.

(p. 7)

Hagni et al. (2008) instructed subjects to imagine that 2D virtual arms were their own. They showed that audio-visual stimulation combined with mental imagery more rapidly elicited an elevated physiological response after an unexpected threat to a virtual limb as compared to audio-visual stimulation alone. They suggested that combining mental imagery with simple

visual input may allow the brain to temporarily incorporate external objects into its body image. Thus, even without high-fidelity realism, sensory input paired with mental imagery can induce ownership that is similar in strength to multimodal input.

Petkova and Ehrsson's 2008 study highlighted the importance of implementing a first person perspective, and stimulating a body part, in extending the RHI to the entire body. In their experiments, participants reported experiencing other people's bodies, as well as artificial bodies, as being their own. The critical conditions they identified to invoke this perceptual illusion were a continuous match between visual and somatosensory information about the state of the body, usage of a sufficiently humanoid body, and the adoption of a first person visual perspective of the body.

Finally, Padilla et al. (2010) pointed out that the effectiveness of a virtual environment relies on presence—that the sense of the user, or part of one's self, is there in the virtual environment, rather than in the current real space. The literature above is a sampling of recent studies that demonstrate the use of bodily illusions via a first-person perspective, with visuo-tactile manipulations, to increase the user's experience of embodying a fake limb or a virtual body.

The current study was initially inspired by the RHI's manipulation of multimodal stimulation and its effect on the physical perception of the self. Further studies have provided evidence that a similar type of synchronous stimulation between the self and another person (rather than one's body and a fake or virtual body) results in a conceptual (rather than physical) merging with the "other." Next discussed is this literature, from which the current study is closely derived: testing the effect of a synchronous haptic experience on conceptual self-other boundaries.

Manipulating the Conceptual Self Boundary with Synchronous Stimulation

Paladino et al. (2010) noted that recent cognitive neuroscience studies support the notion initially expressed in traditional RHI research that the cognitive representation of one's own body or body boundaries appear flexible, dependent on multisensory inputs and feedback, and capable of incorporating extracorporeal body parts.

Paladino et al. consequently investigated whether factors that blur boundaries on the bodily level can also blur boundaries on the conceptual level. In their study, they brushed the cheek of study participants, while participants watched the brushing applied to the face of a stranger shown in a video (in synchronous versus asynchronous conditions). The degree of self-other merging was determined by measuring participants' body sensations, their perception of face resemblance, their judgment of the inner state of the other, the closeness felt toward the other, and conformity behavior.

They concluded that synchronous multisensory stimulation blurs self-other boundaries; participants exposed to synchronous stimulation showed more merging of self and other than participants exposed to asynchronous stimulation. Although the results were subtle, the authors stated that they showed how multisensory integration can affect social perception and create a sense of self-other similarity. They further reported that this is the first time that multisensory integration processes have been shown to have effects on social cognition and behavior:

The current study shows that the cognitive phenomenon of self-other overlap, which is typically experienced with close others and in-group members, can arise from a purely sensorial experience. This adds to findings showing that embodied processes may ground self-other overlap and social identification (Fiske, 2004; Gallace & Spence, 2008; Schubert, Waldzus, & Seibt, 2008). Acting in

synchrony is a common way to implement and communicate a communal relationship that is characterized by the feeling of sameness and unity through a common identity (Fiske, 2004). (Paladino et al., 2010, p. 1205)

Additionally, Paladino et al. cited the relation of synchrony and cooperation discussed by Wiltermuth and Heath (2009), who noted social scientists' speculation that rituals involving synchronous activity may weaken the psychological boundaries between the self and the group. Wiltermuth and Heath's results showed that positive emotions need not be generated for synchrony to foster cooperation, and that acting in synchrony with others can increase cooperation by strengthening social attachment among group members.

In a similar study, Mazurega et al. (2011) examined the effect of using synchronous but arbitrary-related multisensory inputs. In this experiment, participants received electro-tactile stimulations on their cheek, while watching a video of a person illuminated on the cheek with a dot of white light. The stranger stimulated in synchrony was judged as more similar (physically and in terms of personality) and as closer to the self than the stranger stimulated in asynchrony. Additionally, synchronous but not asynchronous stimulations yielded the enfacement effect. This effect creates in the participant the sensations of being in front of a mirror, and is characterized by the illusory sensation of being able to control the facial movements of the person in the video and perceive a resemblance between the face shown in the video and their own face (Paladino et al., 2010; Sforza, Bufalari, Haggard, & Aglioti, 2010; Tsakiris, 2008).

In the Mazurega et al. study, the Inclusion of the Other in the Self Scale revealed that participants felt closer toward the person in the video when the visual stimulation (dots of light) was synchronous rather than asynchronous to the tactile stimulation. When judging the personality and the inner states of the other, the self was used for inferences only when the

stimulation was synchronous. Attraction toward the other and conformity behavior yielded no significant effect.

Thus, synchronous sensorial stimulations affected body perception leading to a blurring of self-other bodily boundaries. When the stimulation was synchronous, participants tended to report touches in the location where they saw the visual stimulation. Furthermore, participants experienced the illusory perception of being the person in the video and being able to control eye and facial movements of the person in the video (Mazzurega et al., 2011).

Mazzurega et al. stated that time is more important than previously experienced links between visual and tactile inputs, and that this finding highlighted the role of temporal synchrony in multisensory interactions. This is consistent with the so-called unity assumption (Welch & Warren, 1980), which describes that when two or more sensory inputs are highly consistent in one or more dimension, observers are likely to treat them as referring to the same underlying multisensory event, thus assuming some sort of unity between them.

Researchers in another study also induced “enfacement” in participants, which creates in the participant the sensations of being in front of a mirror, and which the researchers termed “a novel illusion of personal identity” (Sforza et al., 2010, p. 148). Participants were touched on the face while viewing simultaneous touches on a partner's face. Participants in the synchronous (but not asynchronous) conditions reported that morphed images of themselves and their partner contained more self than other. The researchers thus suggested that the experiment modified self-face recognition by means of a simple psychophysical manipulation, and that facial identity may be more malleable than previously believed. Additionally, enfacement correlated positively with the participant's empathic traits and with the participant's rating of their partner's physical attractiveness.

Although the term “enfacement” was not mentioned in Hatfield et al.’s 1994 text of emotional contagion, it has obvious relevance. Hatfield et al. stated that it is a well-documented fact that faces mirror the emotional facial expressions of those around them. Bavelas, Black, Chovil, Lemery, and Mullett (1988) argued that people are attempting to communicate solidarity and involvement when they mimic others’ postures, and found that when a person mimics another, the symmetry is reflection (as if in a mirror) rather than rotational.

Additionally, motor mimicry can occur at levels so subtle as to produce no observable facial expressions. Davis (1985) argued that true synchronization is not conscious, as such microsynchrony is mediated by basal brain structures. Indeed, Hatfield et al. (1994, p. 82) found that many developmental researchers consider emotional contagion “the most primitive, basic process” (Eisenberg & Strayer, 1987; Zahn-Waxler & Radke-Yarrow, 1990).

In summary, multisensory integration in the rubber hand illusion demonstrates the flexibility of the boundaries of the physical self. Psychophysical manipulation in the enfacement effect (and related experiments) demonstrates the flexibility of boundaries of the conceptual self, from which the current experiment is derived. Specifically, Paladino et al. (2010) brushed the cheek of participants as they watched a stranger’s cheek being brushed in the same way, and synchronous as opposed to asynchronous stimulation resulted in more self-other merging. The current experiment varied these conditions by presenting or not presenting a synchronous haptic experience (i.e., neck massager) between the participant and a stranger and by including verbal feedback from the stranger, which varied between two levels (energy and calm). Next considered is how the findings thus discussed in the literature review are applicable to HCI, which is followed by a discussion of the measurement of the dependent variables in the current study.

Self-Object and Self-Other Boundaries in Human Computer Interaction

The consideration of self-object and self-other boundaries has important implications for the field of HCI. As technology is increasingly a medium with which humans interact, the boundary between the person and the machine is an increasingly salient interaction. Indeed, an interface of any type is defined as a common boundary. Thus, it is possible to design technology with the intention of blurring this boundary (whether physically or conceptually) to augment user experience. The “object” in the self-object boundary in HCI is most commonly a computer screen, and in this study specifically features a person, thus investigating the interaction of the computer user, a haptic device, and an actor on a computer screen. However, interactions with “objects” or “others” in HCI may involve tools such as a mouse, or emerging technologies such as augmented reality or ambient intelligence, and thus the findings of this and related studies are applicable to various HCI domains.

An example of a similar vein of research is Bailenson and Yee’s study (2005) of the automatic assimilation of nonverbal gestures in immersive environments. Participants interacted with an embodied artificial intelligence agent presenting an argument in immersive virtual reality that either mimicked a participant’s head movements at a 4-second delay or utilized prerecorded movements of another participant. They concluded that the mimicking agents were more persuasive and received more positive trait ratings than the non-mimickers, even though participants did not explicitly detect this mimicry. As such progress is made in understanding how the epistemic gulf separating individuals is bridged, this knowledge can be applied to human computer interaction.

Future research could thus explore whether an effect such as emotional contagion might be induced by planned movements (expanding on Wiltermuth & Heath, 2009), by synchronous

facial stimulation (expanding on Paladino et al., 2010), or by a synchronous haptic event (as posited in the current study). Other research questions include whether a synchronous haptic experience could be used to: augment overall user experience; increase a user's feeling of presence with regard to an avatar; increase a user's dramatic involvement with an actor; improve coaching or behavioral modeling; or invoke therapeutic benefits (e.g., stress relief). With regard to designing the illusion of *social* presence in virtual reality, Biocca (1997, p. 22) noted that the perception of the other is based on bodily motions and cues, and he posited that "...it may be possible to develop a medium in which one feels greater access to the intelligence, intentions, and sensory impressions of another than is possible in the most intimate face-to-face communication."

Relatedly, Taylor (2002, p. 42) stated that in an immersive system, a sense of "being there" can be viewed as the construction of a social phenomenon, and thus "bigger, faster, and more highly rendered" may not be as central to presence as once thought. In other words, understanding how our sense modalities process social phenomena, and how to implement this knowledge, may be just as important as computing power or 3D graphics in HCI innovation.

Indeed, in terms of human modalities for sensory perception and interaction, HCI typically emphasizes vision, whereas the contribution of haptics has been minimal by comparison. This oversight with regard to haptics and touch carries over to the behavioral sciences as well, as noted by Gallace and Spence (2010, p. 247):

Far more research appears to have been devoted to investigating the more emotional aspects of our other senses, such as vision and audition (and to a lesser extent olfaction and taste), than of our sense of touch (e.g., Ekman, 1993; Ekman

et al., 1972; Fecteau et al., 2007; Johnstone et al., 2006; Nass and Brave, 2005; O'Doherty et al., 2001; Veldhuizen et al., 2006).

According to Ionta, Gassert, and Blanke (2011), the recent evidence provided by RHI and enfacement experiments suggest that low-level bottom-up mechanisms of multi-sensory integration play a fundamental role in encoding specific components of bodily self-consciousness, and they note that multi-sensory conflicts can be used to manipulate more global aspects of body perception. They concluded that multi-sensory integration is a key brain mechanism for self-consciousness and suggested that future work take a multidisciplinary approach that considers the interaction of visuo-tactile integration with vestibular, proprioceptive, and cognitive motor signals.

In an example of such HCI innovation, Hook (2012) described her students' development of a breathing sensor for users that mirrors the behavior of the user's character in the game. Synchronizing one's breath with the avatar's breath was necessary for game success, and Hook asserted that this type of experience is key to HCI design processes. "Without them we cannot create compelling and meaningful interactions in dialogue with our prospective users. But articulation of these experiences in academic texts is lacking—and sometimes very hard to capture. ... The *dynamic gestalt* of the interaction does not reveal itself to you until you experience it" (Hook, 2012, p. 10).

In light of these gaps in research and practice, the current study examines how the presence versus absence of sharing a haptic experience with an actor in a video (who reports the experience to be either energizing or calming) affects psychophysiology, mood, and social perceptions. The next sections cover the literature addressing the measurement of the outcome variables of the present study, which is followed by the study's hypotheses.

Measuring Emotional Contagion via Change in Mood

Measuring affect in HCI research is a challenging and complex issue (Shami, Hancock, Peter, Muller, & Mandryk, 2008); indeed, measuring a person's emotional state is one of the most vexing problems in affective science (Mauss & Robinson, 2009). Emotional response in part involves physiology, in particular, the peripheral/autonomic nervous system and the central nervous system (Mauss & Robinson, 2009). Because classic research and reviews have found that ANS activation more reliably covaries with the intensity rather than the valence of emotions (Hatfield, Cacioppo, & Rapson, 1994), arousal rather than valence was manipulated and evaluated in this study.

Thayer (1989) identified two very basic mood-behavior orientations: energetic arousal and tense arousal. The energetic arousal mood system describes a dichotomy consisting at one end of feelings of energy that “predispose a person to move, to act, to be physically active.” At the other end, “declines in these feelings, together with feelings of tiredness, generally impel rest or inaction” (Thayer, 1989, p. 6). Thus, it is this mood dichotomy that is enacted in the two videos as an experimental factor.

This study generally uses the term “mood” rather than “affect” or “emotion” because this author is employing the dichotomy that Thayer (1989) termed a “mood system,” and because Wilhelm and Schoebi's (2007) scale that was used is described as a mood scale. However, as Thayer (1989, p. 14) pointed out, “mood,” “affect,” and “emotion” “...are often used interchangeably in both technical and popular language.” Although some differences can be detected, there is a great deal of overlap. Thus, the term “mood” is being used here for rather mundane reasons—“emotion” or “affect” could also be appropriate terms for this measurement.

Skin conductance level (also known as the galvanic skin response; hereinafter referred to as “skin conductance”) is widely used for monitoring mood, by measuring change in the conductivity of the skin (i.e., change in conductance due to the amount of sweat level in the eccrine sweat gland) (Healey, Nachman, Subramanian, Shahabdeen, & Morris, 2010). This sweating, however, is not merely thermoregulatory; eccrine glands of palms and fingers respond only weakly to heat and strongly to psychological and sensory stimuli. From its beginning uses in the late 1800s, changes in the electrical activity of the skin were measured to assess arousal to sensory or emotional stimuli, and an increase in skin conductance generally means increased arousal and/or attention (Andreassi, 2000).

Schwartz and Shapiro (1973) reviewed the long history of electrodermal activity in social psychophysiology research and concluded that it appears to be an excellent dependent variable. Measures such as skin conductance offer both high sensitivity to psychological stimuli and ease of measurement. Skin conductance is a relatively reliable index for sweat gland activity and changes in activation level of the sympathetic nervous system (Mohan, Sharma, & Bijlani, 2011).

However, Schwartz and Shapiro (1973) also stated that social psychophysiology research should consider other measures, such as heart rate or pulse volume, since different systems may be sensitive to different aspects of a task or condition. Heart rate variability is an accessible tool that can help reveal the role of emotion in social processes (Appelhans & Luecken, 2006).

Numerous studies have shown skin conductance and heart rate to be reliable and accurate measures of change in affect (e.g., Bugental, Blue, Cortez, Fleck, & Rodriguez, 1992; Lee et al., 2005; Nasoz, Alvarez, Lisetti, & Finkelstein, 2004). Drachen, Nacke, Yannakakis, & Pedersen (2010) reported that psychophysiological methods are being used in video game research as

measures of emotion and cognition, and offer a quantitative understanding of affective player experience. Specifically, heart rate and skin conductance have been used as measures of relaxation versus stress, energy, or arousal. For example, computer game stress was associated with a significant increase in physiologic markers of stress, including heart rate and skin conductance, whereas meditation-induced relaxation was associated with decreases (Mohan, Sharma, & Bijlani, 2011). In other contexts, one-minute presentations of each primary color have been shown to affect skin conductance differently (Jacobs & Hustmyer, 1974), whereas stimulative music has been shown to increase heart rate (Lingham & Theorell, 2009).

Emotional response also in part involves subjective experience (Mauss & Robinson, 2009). Thus an accompanying subjective pre- and post-intervention measure of affect is appropriate. Wilhelm and Schoebi (2007)'s short mood scale (see Appendix B) is a parsimonious six-item bi-polar mood measure that was developed to assess three basic dimensions of mood in people's daily lives—valence (ranging from unpleasant to pleasant), calmness (ranging from restless/under tension to calm/relaxed), and energetic arousal (ranging from tired/without energy to awake/full of energy). Calmness and energetic arousal were examined in this study, since as noted above, autonomic nervous system activation more reliably covaries with affective intensity rather than valence.

Measuring Self-Other Conceptual Boundaries

Aron, Aron, and Smollen (1992) developed the Inclusion of Other in the Self Scale (IOS Scale) as a single-item pictorial measure intended to tap directly people's sense of interpersonal interconnectedness. The scale was intended to be consistent with many theoretical orientations (Aron, Aron, & Smollen, 1992). Schubert and Otten (2002) modified this scale for ingroup-outgroup relations. They noted that things that go together tend to be in the same bounded

region, and in the social environment social relations often manifest themselves in an analogous fashion via spatial relations. In other words, the ways we conceptualize, reason about, or visualize our experiences are influenced by the sensorimotor domain (Lakoff & Johnson, 1999), and this scale is intended to capture that perception. Paladino et al. (2010), in finding that synchronous multisensory stimulation blurs self-other boundaries, used a version of Schubert and Otten's (2002) IOS scale as a measure of self-other merging, which was used in this study (Appendix C).

Other studies have used questions to measure conceptual boundaries. In their study of synchrony and cooperation, Wiltermuth and Heath (2009) asked the question: "How connected did you feel with the other participants during the walk?" In the experimental condition, participants walked in step, whereas in the control they walked normally. Participants in the synchronous condition reported feeling more connected with their counterparts than those in the asynchronous condition. Liviatan, Trope, and Liberman (2008) studied the manner in which interpersonal similarity influenced the representation and judgment of others' actions, building on the concept of such similarity as an assessment of social distance. Their measures included asking the participants how similar the target was to them, how close they felt to the target, and how much they liked the target. The four questions used in this study are derived from these questions (Appendix D). The sum of the IOS Scale plus these four questions resulted in what is termed in this study an "interpersonal closeness" measure.

Hypotheses

Hypothesis 1 suggests that the energy video would have an energizing effect (increase in heart rate and skin conductance; increase on energetic arousal measure) and the calm video would have a calming effect (decrease in heart rate and skin conductance; increase on calmness

measure) in both the haptic and no haptic conditions, due to emotional contagion. Hypothesis 1 further predicts that in the haptic conditions, these effects would be greater due to the synchronous haptic experience with the actor. In other words, the neck massager is intended to heighten similarity and familiarity and is expected to aid in blurring the conceptual boundary between participant and actor in the haptic conditions. The synchronous haptic experience is hypothesized to convey “sameness” in both the tactile modality as well as the visual modality (in which it may be conceived as a shared morphology), thus aiding in the transmission of the actor’s mood.

Likewise, it is anticipated that the presence of the haptic device (the synchronous haptic experience) will result in participants perceiving a closer connection to the actor. Hypothesis 2 then suggests that participants in both the haptic-energy video and haptic-calm video conditions (as compared to those in the two no haptic conditions) would realize a pre-post gain on the interpersonal closeness measure.

CHAPTER 3. METHODS AND PROCEDURES

Overview

The study is a three-factor, between and within participants experiment, with 12 participants in each of the 4 conditions (Table 1). With regard to the physiological measures, the study is a 2 (Haptic or No Haptic) x 2 (Energy Video or Calm Video) x 3 (Pre, Post 1, and Post 2 repeated measures) factorial design. With regard to the self-report measures, the study is a 2 (Haptic or No Haptic) x 2 (Energy Video or Calm Video) x 2 (Pre and Post repeated measures) factorial design. The independent variables are: (1) the presence or absence of haptic input (a neck massager); (2) one of two videos (energy or calm); and (3) the time factor. The experiment measures the effect of these variables on the following dependent variables: (1) heart rate; (2) skin conductance; (3) energetic arousal; (4) calmness; and (5) interpersonal closeness to the actor.

Independent Variables

The rubber hand illusion and related experiments have generally used a correlation between visual and tactile inputs to induce the illusion of incorporating an extracorporeal object into one's body representation or to induce feelings of embodiment in a virtual body. Some consequent studies have examined whether these effects might extend beyond body perception to the conceptual merging of self and other, and have demonstrated that multisensory integration processes did appear to affect social cognition and behavior (Mazzurega et al., 2011; Paladino et al., 2010). As reviewed, Paladino et al. (2010) brushed the cheek of each participant as he or she watched a stranger's cheek being brushed in the same way, and synchronous as opposed to asynchronous stimulation resulted in more self-other merging.

Table 1

Experimental Design

| | Measures | Energy Video | | | Calm Video | | |
|-----------|-------------------------|-----------------|--------|--------|-----------------|--------|--------|
| | | Pre | Post 1 | Post 2 | Pre | Post 1 | Post 2 |
| Haptic | Heart rate | X | X | X | X | X | X |
| | Skin conductance | X | X | X | X | X | X |
| | Energetic arousal | X | -- | X | X | -- | X |
| | Calmness | X | -- | X | X | -- | X |
| | Interpersonal closeness | X | -- | X | X | -- | X |
| | | 12 participants | | | 12 participants | | |
| No Haptic | Heart rate | X | X | X | X | X | X |
| | Skin conductance | X | X | X | X | X | X |
| | Energetic arousal | X | -- | X | X | -- | X |
| | Calmness | X | -- | X | X | -- | X |
| | Interpersonal closeness | X | -- | X | X | -- | X |
| | | 12 participants | | | 12 participants | | |

The current experiment varied these conditions by:

- (1) Presenting or not presenting the neck massager, which served as a synchronous haptic experience between the participant and the actor in a video. The effect of tactile stimulation being synchronous and “visually-captured” has been demonstrated, so this study investigated the effects of a “synchronous haptic event” in which the stimulation is more tactile rather than visual; and
- (2) Including verbal content from the actor in the video, which varied between two levels. For example, in the energizing video, the actor said the neck massager acted like coffee in making her energized, and in the calming video she said it acted like herbal tea to make her calm. Appendix A includes the complete video scripts.

Dependent Variables

Two categories of dependent variables were of interest. One was the mood change from pre-video to post-video, which was a proxy for emotional contagion (the blurring of the conceptual boundary between the participant and the actor). This was measured by changes in heart rate and skin conductance, and subscales of Wilhelm and Schoebi (2007)'s short mood scale (see Appendix B).

Wilhelm and Schoebi (2007) developed and evaluated the psychometric properties of a six-item scale based on the Multidimensional Mood Scale (Steyer, Schwenkmezger, Notz, & Eid, 1997). Wilhelm and Schoebi had participants respond to the statement "At this moment I feel..." by means of six bipolar items, to which participants circled a number from zero to six to reflect their mood. They concluded that the scale's three factors, Calmness, Valence, and Energetic Arousal, were appropriate to assess fluctuations within persons over time. At the between-person level, reliability was .92 for Valence, and .90 for Calmness and Energetic Arousal. Data from three items were reverse coded, to ensure that higher scores indicate higher positive Valence, higher Energetic Arousal, or higher Calmness. The factors of Calmness versus Energetic Arousal are of particular interest in this study, as measured by four of the items. With reverse coding implemented, calmness ranges from 0 (*very calm*) to 6 (*very agitated*), and 0 (*very relaxed*) to 6 (*very tense*); energetic arousal ranges from 0 (*very tired*) to 6 (*very awake*) and 6, and 0 (*very without energy*) and 6 (*very full of energy*).

The second variable of interest is the self-other boundary, as manifested in the participant's perception of interpersonal closeness to the actor. Participants responded to Paladino et al.'s (2010) version of Schubert and Otten's (2002) IOS scale (originally developed by Aron, Aron, & Smollan, 1992) (Appendix C). The 7-point scale consists of a series of circles

representing the self and the other person with different degrees of overlap, from two distant circles (score = 1) to two completely overlapping circles (score = 7). Aron et al. (1992)'s reliability check (test-retest) showed correlations between the original and the 2-week retesting were $r = .83$ overall. Other measures supported the concurrent validity of the IOS Scale (i.e., what it measures overlaps in a general way with other measures, each of which has either obvious face validity or some degree of empirical validity of its own). From their series of studies, Aron et al. (1992) concluded that the IOS Scale had a reasonable level of predictive validity and had the psychometric and substantive suitability as a measure of closeness.

Also to assess the self-other boundary, participants responded to the questions “How connected did you feel with the actor?”, “How similar is the actor to yourself?”, “How close do you feel to the actor,” and “How much do you like the actor?”, using a 9-point Likert scale (1 = *not at all*, 9 = *very much*). These questions were derived from Wiltermuth and Heath (2009) and Liviatan et al. (2008), as discussed in the review of literature, and for which reliability was not reported. The sum of these questions and the IOS Scale resulted in the interpersonal closeness measure. The Cronbach's alpha for these five items in this study was .87.

Apparatuses and Actor

The device used for haptic input was the Brookstone Shiatsu Neck and Shoulder Massager (Figure 1). Generally, haptic interaction developed for the human-computer interface focuses on the hands, since the primary tactile interaction involves the hand or hands (e.g., keyboard, mouse, trackpad, game controller, cellular phone, tablet) and a feedback loop that allows for user manipulation (van Erp, 2002). However, in this experiment, the author sought a device with which the participant could plainly observe the actor receiving the same haptic experience (i.e., a common “morphology,” Preston & de Waal, 2002). Because the haptic

component is passive and thus incorporates no feedback, it was possible to venture beyond the typical hand-centric interaction. Experimental use of this particular neck massager was not found in the literature, but a similar device (Homedics “Back Therapist Deluxe”) had been used in exploring suppression of pain-related thoughts and feelings during pain-induction (Burns, Elfant, & Quartana, 2010; Elfant, Burns, & Zeichner, 2008).



Figure 1. Actor wearing Brookstone Shiatsu Neck and Shoulder Massager

Heart rate and skin conductance were measured with the FlexComp Infiniti Encoder. Video of the actor was recorded digitally on a Flip Video Camera and was viewed by participants on a 15-inch MacBook. The actor was an 18-year-old college freshman, recruited via the theater department. Appendix A includes the content of each video.

Participants

Healthy females between the ages of 18 and 30 were recruited via advertisements posted on campus and email invitations (with email addresses procured from the Registrar’s office). Gender and age could be confounding factors, and therefore the study sought a somewhat

homogenous sample of participants who resembled the actor in the video in terms of age and gender. Each participant received a \$10 Caribou Coffee gift card for her participation.

Forty-eight women participated in the study. They ranged in age from 18 to 29, with a mean age of 21.29 ($SD=2.68$). All were full-time students. About two-thirds (33) identified their race as White, whereas nine were Asian, two were Black or African American, and four offered multiple choices or left the question blank. About 90 percent (44) were not Hispanic or Latino, whereas three were Hispanic or Latino, and one left the question blank.

Each of the forty-eight participants were randomly assigned to one of the four conditions, so that there were 12 participants in each condition (Table 1). Related studies have used 10 to 18 participants per condition (Mazzurega et al., 2011; Paladino et al., 2010; Wiltermuth & Heath, 2009).

Procedure

The investigator (author) conducted the experiment in a small room with two tables—a table for the participant to sit at, with a MacBook for viewing the actor photo and video, and another table for the investigator. The investigator's table was at a 90-degree angle to the participant to conceal the recording of the physiological data on the PC laptop. The room temperature was kept at a constant 68 to 70 degrees Fahrenheit.

The investigator's PC laptop contained the software used for the recording of physiological data: Biograph Infiniti Version 5.0.3 by Thought Technology Ltd., using channel set "PI Physiology Suite BVP." The accompanying hardware was FlexComp by Thought Technology Ltd., and consisted of the encoder, the SC-Flex/Pro sensor (for skin conductance), and the BVP-Flex/Pro sensor (for heart rate). A cell phone stopwatch was synchronized with the start of the Biograph to aid in monitoring event timing.

The paper documentation for each participant was a consent form, a demographic questionnaire, and two study questionnaires (pre and post) of two pages each. Each participant was randomly assigned to one of the four conditions.

In the e-mail scheduling of each participant, the investigator confirmed that the person was a female aged 18 to 30, and that she agreed not to exercise in the three hours prior to arrival, nor run or rush over to the study. Upon arrival, the participant read and signed consent documentation approved by the Institutional Review Board (IRB approval letter is provided in Appendix E). The investigator next attached the skin conductance sensors to the middle and ring fingers of the participant's non-dominant hand, after wiping the fingers and sensors with alcohol. Then the investigator attached the BVP sensor to the index finger. The participant's hand with sensors was placed palm up on a towel. The participant was asked to leave this hand immobile for the duration of the experiment.

The investigator simultaneously began recording on the Biograph Infiniti and started the stopwatch application. The participant responded to the brief demographic questionnaire and the Short Mood Scale. The investigator showed a still of the actor wearing the neck massager on the MacBook, and the participant responded to the interpersonal closeness measure.

A rest period began, which took a total of 15 minutes from the start of the Biograph recording. The participant was offered a word search booklet to work on—a neutral activity to pass time.

About one minute prior to the start of the video (the 14-minute mark), the investigator placed the neck massager on the participant if she was assigned to the haptic condition. At the 15-minute mark, the investigator began the video—either calming or energizing, depending on

the assignment. If the participant was in the neck massager condition, the investigator turned on the neck massager immediately after starting the video.

At the conclusion of the 3-minute video, the investigator turned off the neck massager (if applicable) and asked the participant to again respond to the Short Mood Scale. After showing the still of the actor wearing the neck massager on the MacBook, the participant again responded to the interpersonal closeness measure. The participant was then offered the word search booklet for the few remaining minutes of physiological data recording. When the recording/stopwatch exceeded 23.5 minutes, the investigator stopped the recording and disconnected the sensors.

The period of physiological pre-data was defined as the five minutes prior to the start of the video. Two five-minute post-data periods were defined. Post 1 started one minute after the start of the video and Post 2 started at the conclusion of the video (see Table 2).

Table 2

Timeline of Experimental Procedure With Description of Events and Periods

| Minutes | Description | Periods | | | | |
|---------|--|---------|--------------------------------------|--------------------------------------|--|--|
| 0-1 | Commence recording; pre-questionnaires, followed by word search (neutral activity) | | | | | |
| 1-2 | | | | | | |
| 2-3 | | | | | | |
| 3-4 | | | | | | |
| 4-5 | | | | | | |
| 5-6 | | | | | | |
| 6-7 | | | | | | |
| 7-8 | | | | | | |
| 8-9 | | | | | | |
| 9-10 | | | | | | |
| 10-11 | | | | | | |
| 11-12 | | | | | | |
| 12-13 | | | | | | |
| 13-14 | | | | | | |
| 14-15 | | | | | | |
| 15-16 | Presentation of video Minutes 15 to 18 | | | | | |
| 16-17 | | | | | | |
| 17-18 | | | | | | |
| 18-19 | Post-questionnaires, followed by resumption of word search | | Post 1 Minutes 16 to 21 | | | |
| 19-20 | | | | | | |
| 20-21 | | | | Post 2 Minutes 18 to 23 | | |
| 21-22 | | | | | | |
| 22-23 | | | | | | |
| 23-24 | Stop recording | | | | | |

CHAPTER 4. RESULTS

A 2 (Haptic versus No Haptic) x 2 (Energy Video versus Calm Video) x 3 (Pre- versus two Post-interventions) analysis of variance for the physiological dependent measures and a 2 (Haptic versus No Haptic) x 2 (Energy Video versus Calm Video) x 2 (Pre- versus Post-intervention) analysis of variance for the self-report dependent measures were computed, with repeated measures on the last factor. First, the main effects for haptic, video, and time are presented. Although main effects were not predicted by the hypotheses, they are conventionally addressed first in experimental results, and thus that practice is followed here. Second, interaction effects of Haptic x Time, Video x Time, and Haptic x Video x Time are presented, and the hypotheses addressed where relevant.

There were no significant main effects for either haptic or video, which are addressed in Tables 3 and 4, respectively. However, there was a significant main effect for time for all measures (Table 5). Each of these measures is considered below in turn.

There was a significant main effect for heart rate over time (blood volume pulse heart rate from inter-beat interval), $F(1, 44) = 8.00, p = < .01$. Pairwise comparisons using Bonferroni adjusted alpha revealed a significant effect between each of the three periods of heart rate measurement. From Pre to Post 1 there was a mean decrease of 2.14 ($p < .001$). From Post 1 to Post 2 there was a mean increase of .98 ($p < .001$). The decrease between Pre and Post 2 was 1.16 ($p < .05$). The data suggests that after a decrease between Pre and Post 1, Post 2 then increased toward the Pre-period (baseline) (Figure 2).

Table 3

Mean Differences of Heart Rate, Skin Conductance, Calmness, Energetic Arousal, and Interpersonal Closeness By Haptic Condition

| Measure | Haptic | No Haptic | <i>F</i> | η_p^2 |
|-------------------------|-----------------------------------|-----------------------------------|----------|------------|
| Heart Rate | 76.69 (2.50) [71.64, 81.74] | 77.32 (2.50) [72.28, 82.37] | .03 | 0 |
| Skin Conductance | 5.22 (1.04) [3.12, 7.33] | 5.49 (1.04) [3.39, 7.60] | .03 | 0 |
| Calmness | 8.58 (.51) [7.56, 9.61] | 9.10 (.51) [8.08, 10.13] | .52 | .01 |
| Energetic Arousal | 7.54 (.39) [6.75, 8.34] | 7.00 (.39) [6.21, 7.80] | .94 | .02 |
| Interpersonal Closeness | 17.83 (1.30) [15.22, 20.45] | 18.58 (1.30) [15.97, 21.20] | .17 | 0 |

Note. Below the means are standard errors in parentheses and 95% confidence intervals in brackets.

Table 4

Mean Differences of Heart Rate, Skin Conductance, Calmness, Energetic Arousal, and Interpersonal Closeness By Video Condition

| Measure | Energy Video | Calm Video | <i>F</i> | η_p^2 |
|-------------------------|-----------------------------------|-----------------------------------|----------|------------|
| Heart Rate | 77.22 (2.50) [72.17, 82.27] | 76.79 (2.50) [71.75, 81.84] | .01 | 0 |
| Skin Conductance | 4.65 (1.04) [2.55, 6.75] | 6.07 (1.04) [3.97, 8.17] | .92 | .02 |
| Calmness | 8.75 (.51) [7.72, 9.78] | 8.94 (.51) [7.91, 9.96] | .07 | 0 |
| Energetic Arousal | 7.77 (.39) [6.98, 8.57] | 6.77 (.39) [5.98, 7.57] | 3.22 | .07 |
| Interpersonal Closeness | 18.63 (1.30) [16.01, 21.24] | 17.79 (1.30) [15.17, 20.41] | .21 | .01 |

Note. Below the means are standard errors in parentheses and 95% confidence intervals in brackets.

Table 5

Changes of Heart Rate, Skin Conductance, Calmness, Energetic Arousal, and Interpersonal Closeness Over Time

| Measure | Pre | Post 1 | Post 2 | <i>F</i> | η_p^2 |
|-------------------------|---|---|---|----------|------------|
| Heart Rate | 78.11 _a (12.54) [74.38, 81.84] | 75.97 _b (11.93) [72.44, 70.50] | 76.95 _c (11.90) [73.42, 80.47] | 8.00** | .15 |
| Skin Conductance | 4.57 _a (4.81) [3.15, 5.99] | 5.71 _b (5.14) [4.20, 7.23] | 5.79 _b (5.21) [4.25, 7.33] | 60.85*** | .58 |
| Calmness | 8.40 (2.92) [7.57, 9.22] | -- | 9.29 (2.67) [8.49, 10.09] | 6.037* | .12 |
| Energetic Arousal | 7.77 (2.18) [7.15, 8.39] | -- | 6.77 (2.47) [6.08, 7.46] | 8.82** | .17 |
| Interpersonal Closeness | 16.46 (6.07) [14.69, 18.23] | -- | 19.96 (8.63) [17.44, 22.48] | 9.53** | .18 |

Note. Below the means are standard deviations in parentheses and 95% confidence intervals in brackets. Means with differing subscripts within rows are significantly different at the $p \leq .05$ based on Bonferroni adjustment for multiple comparisons.

* $p \leq .05$. ** $p \leq .01$. *** $p \leq .001$.

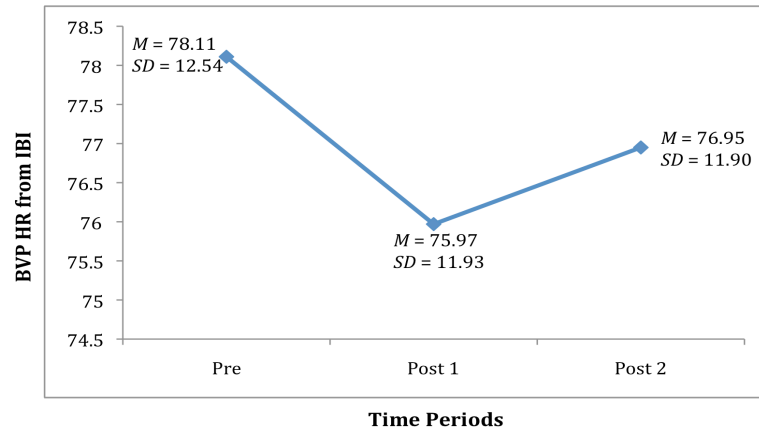


Figure 2. Mean heart rate (all conditions) across time

There was a significant main effect for skin conductance levels in micro-Siemens (μS) over time, $F(1, 44) = 60.85$, $p < .001$. Pairwise comparisons using Bonferroni adjusted alpha revealed a significant difference between the Pre period and the two Post periods of skin conductance measurement. From Pre to Post 1 there was a mean increase of 1.14 ($p < .001$). The mean increase between Pre and Post 2 was 1.25 ($p < .001$). The .08 increase between Post 1 and Post 2 was not significant (Figure 3).

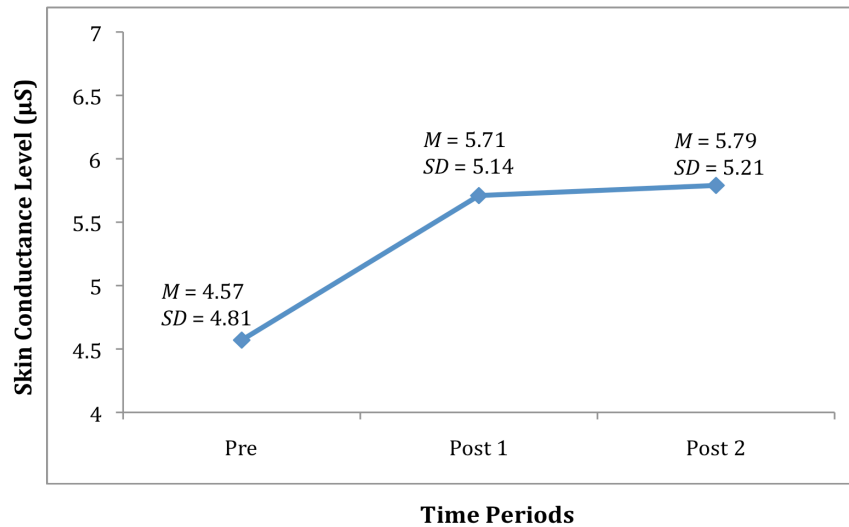


Figure 3. Mean skin conductance (all conditions) across time

The main effects over time for the self-report measures were that the scores for calmness increased, $F(1, 44) = 6.04, p = < .05$, the scores for energetic arousal decreased, $F(1, 44) = 8.82, p = < .01$, and the scores for interpersonal closeness increased, $F(1, 44) = 9.53, p = < .01$. Additionally, there were three-way interaction effects for calmness and interpersonal closeness, which are discussed last.

There were no significant effects for either Haptic x Time (Table 6) or Video x Time (Table 7). Hypothesis 1 predicted that the energy video would have an energizing effect, resulting in an increase between the pre- and post-measures of heart rate, skin conductance, and energetic arousal. Also, Hypothesis 1 predicted that the calm video would have a calming effect, resulting in a decrease between pre- and post-measures of heart rate and skin conductance, and an increase between pre- and post-measures of calmness. It was further expected that these differences would be greater in the haptic conditions. There were, however, no significant effects for video across time for any of the measures (Table 7).

Table 8 shows the values for Haptic x Video x Time. A three-way interaction effect was found for two measures.

First, the calmness measure produced a three-way interaction effect, $F(1, 44) = 7.21, p = < .01$. A paired samples t-test revealed that one condition showed a significant pre-post increase: haptic-energy video ($p = < .05$) (Figure 4). This is in contradiction to Hypothesis 1, which predicted that both the haptic-calm video and no haptic-calm video conditions would result in an increase in calmness.

Table 6

Changes of Heart Rate, Skin Conductance, Calmness, Energetic Arousal, and Interpersonal Closeness Over Time in Haptic and No Haptic Conditions

| Measure | Pre | <u>Haptic</u> | | Pre | <u>No Haptic</u> | | <i>F</i> | η_p^2 |
|----------------------------|---------------------------------------|---------------------------------------|---------------------------------------|---------------------------------------|---------------------------------------|---------------------------------------|----------|------------|
| | | Post 1 | Post 2 | | Post 1 | Post 2 | | |
| Heart Rate | 77.49 (12.63) [72.22, 82.77] | 75.93 (12.77) [70.94, 80.92] | 76.65 (12.57) [71.66, 81.64] | 78.72 (12.68) [73.45, 84.00] | 76.00 (11.32) [71.01, 80.99] | 77.24 (11.46) [72.26, 82.23] | .61 | .01 |
| Skin Conductance | 4.44 (3.54) [2.43, 6.45] | 5.53 (4.06) [3.38, 7.67] | 5.70 (4.11) [3.52, 7.88] | 4.70 (5.88) [2.69, 6.71] | 5.90 (6.12) [3.75, 8.04] | 5.89 (6.21) [3.71, 8.07] | .04 | .00 |
| Calmness | 7.96 (2.93) [6.79, 9.13] | -- | 9.21 (3.02) [8.07, 10.34] | 8.83 (2.90) [7.67, 10.00] | -- | 9.38 (2.34) [8.24, 10.51] | .94 | .02 |
| Energetic Arousal | 7.83 (2.48) [6.95, 8.72] | -- | 7.25 (2.66) [6.28, 8.22] | 7.71 (1.88) [6.83, 8.59] | -- | 6.29 (2.22) [5.32, 7.26] | 1.53 | .03 |
| Interpersonal Closeness | 15.42 (5.00) [12.91, 17.92] | -- | 20.25 (9.34) [16.69, 23.81] | 17.50 (6.93) [15.00, 20.00] | -- | 19.67 (8.04) [16.12, 23.23] | 1.38 | .03 |

Note. Below the means are standard deviations in parentheses and 95% confidence intervals in brackets. *F* value is Haptic x Time interaction effect.

Table 7

Changes of Heart Rate, Skin Conductance, Calmness, Energetic Arousal, and Interpersonal Closeness Over Time in Energy Video and Calm Video Conditions

| Measure | <u>Energy Video</u> | | | <u>Calm Video</u> | | | <i>F</i> | η_p^2 |
|----------------------------|---------------------------------------|---------------------------------------|---------------------------------------|---------------------------------------|---------------------------------------|---------------------------------------|----------|------------|
| | Pre | Post 1 | Post 2 | Pre | Post 1 | Post 2 | | |
| Heart Rate | 77.97 (12.89) [72.69, 83.24] | 76.35 (12.77) [71.36, 81.34] | 77.34 (12.60) [72.36, 82.33] | 78.25 (12.44) [72.97, 83.52] | 75.58 (11.30) [70.60, 80.58] | 76.55 (11.41) [71.56, 81.54] | 1.73 | .04 |
| Skin Conductance | 3.88 (3.23) [1.87, 5.89] | 4.99 (3.80) [2.85, 7.14] | 5.07 (3.92) [2.89, 7.26] | 5.26 (5.98) [3.25, 7.27] | 6.43 (6.20) [4.28, 8.57] | 6.51 (6.25) [4.33, 8.70] | .04 | .00 |
| Calmness | 8.21 (3.02) [7.04, 9.38] | -- | 9.29 (2.76) [8.16, 10.43] | 8.58 (2.86) [7.42, 9.75] | -- | 9.29 (2.65) [8.16, 10.43] | .26 | .01 |
| Energetic Arousal | 8.00 (1.96) [7.12, 8.88] | -- | 7.54 (2.75) [6.57, 8.51] | 7.54 (2.40) [6.66, 8.42] | -- | 6.00 (1.91) [5.03, 6.97] | 2.59 | .06 |
| Interpersonal Closeness | 16.42 (6.23) [13.91, 18.92] | -- | 20.83 (9.62) [17.28, 24.39] | 16.50 (6.04) [14.00, 19.00] | -- | 19.08 (7.62) [15.53, 22.64] | .65 | .02 |

Note. Below the means are standard deviations in parentheses and 95% confidence intervals in brackets. *F* value is Video x Time interaction effect.

Table 8

Changes of Heart Rate, Skin Conductance, Calmness, Energetic Arousal, and Interpersonal Closeness Over Time for Haptic-Energy Video, Haptic-Calm Video, No Haptic-Energy Video, and No Haptic-Calm Video

| Measure | <u>Haptic-Energy Video</u> | | | <u>Haptic-Calm Video</u> | | |
|----------------------------|---------------------------------------|--------------------------------------|---------------------------------------|---------------------------------------|---------------------------------------|---------------------------------------|
| | Pre | Post 1 | Post 2 | Pre | Post 1 | Post 2 |
| Heart Rate | 79.00 (13.36) [71.54, 86.46] | 78.42 (3.22) [71.36, 85.48] | 78.96 (13.08) [71.91, 86.01] | 75.98 (12.26) [68.52, 83.44] | 73.44 (12.34) [66.38, 80.50] | 74.34 (12.14) [67.29, 81.39] |
| Skin Conductance | 4.24 (3.38) [1.39, 7.08] | 5.43 (3.90) [2.40, 8.46] | 5.51 (3.98) [2.43, 8.60] | 4.64 (3.85) [1.80, 7.49] | 5.63 (4.38) [2.59, 8.66] | 5.89 (4.41) [2.80, 8.97] |
| Calmness | 6.92 (3.32) [5.27, 8.57] | -- | 9.33 (3.93) [7.73, 10.94] | 9.00 (2.13) [7.35, 10.65] | -- | 9.08 (2.75) [7.48, 10.69] |
| Energetic Arousal | 8.67 (2.10) [7.42, 9.91] | -- | 8.17 (3.01) [6.79, 9.54] | 7.00 (2.63) [5.75, 8.25] | -- | 6.33 (1.97) [4.96, 7.71] |
| Interpersonal Closeness | 14.33 (5.37) [10.79, 17.87] | -- | 23.00 (11.38) [17.97, 28.03] | 16.50 (4.58) [12.96, 20.04] | -- | 17.50 (6.05) [12.47, 22.53] |

(table continues)

Table 8 (continued)

| Measure | No Haptic-Energy Video | | | No Haptic-Calm Video | | | <i>F</i> | η_p^2 |
|-------------------------|---------------------------------------|---------------------------------------|---------------------------------------|---------------------------------------|---------------------------------------|---------------------------------------|----------|------------|
| | Pre | Post 1 | Post 2 | Pre | Post 1 | Post 2 | | |
| Heart Rate | 76.93 (12.92) [69.47, 84.39] | 74.28 (12.52) [67.22, 81.34] | 75.73 (12.45) [68.68, 82.78] | 80.52 (12.74) [73.06, 87.98] | 77.73 (10.22) [70.67, 84.79] | 78.76 (10.69) [71.70, 85.81] | .39 | .01 |
| Skin Conductance | 3.52 (3.19) [.68, 6.37] | 4.56 (3.82) [1.52, 7.59] | 4.64 (3.99) [1.55, 7.72] | 5.87 (7.70) [3.03, 8.72] | 7.23 (7.73) [4.20, 10.27] | 7.14 (7.83) [4.06, 10.23] | .01 | .00 |
| Calmness | 9.50 (2.11) [7.85, 11.15] | -- | 9.25 (2.09) [7.65, 10.86] | 8.17 (3.49) [6.62, 9.82] | -- | 9.50 (2.65) [7.90, 11.11] | 7.21** | .14 |
| Energetic Arousal | 7.33 (1.61) [6.09, 8.58] | -- | 6.92 (2.43) [5.54, 8.29] | 8.08 (2.11) [6.84, 9.33] | -- | 5.67 (1.87) [4.29, 7.04] | 1.85 | .04 |
| Interpersonal Closeness | 18.50 (6.56) [14.96, 22.04] | -- | 18.66 (7.34) [13.63, 23.70] | 16.50 (7.44) [12.96, 20.04] | -- | 20.67 (8.91) [15.63, 25.70] | 6.62* | .13 |

Note. Below the means are standard deviations in parentheses and 95% confidence intervals in brackets. *F* value is Haptic x Video x Time interaction effect.

* $p \leq .05$. ** $p \leq .01$.

Second, there was a three-way interaction effect for interpersonal closeness, $F(1, 44) = 6.62, p = < .05$. A paired samples t-test revealed that two conditions showed a significant pre-post increase: haptic-energy video and no haptic-calm video ($p = < .05$) (Figure 5). Hypothesis 2 predicted that participants in both the haptic-energy video and haptic-calm video conditions (as compared to those in the two no haptic conditions) would realize a pre-post gain on the interpersonal closeness measure. Therefore, Hypothesis 2 was confirmed by the significant

results in the haptic-energy video condition, but contradicted by the significant results in no haptic-calm video condition, as well as the lack of effect in the haptic-calm video condition.

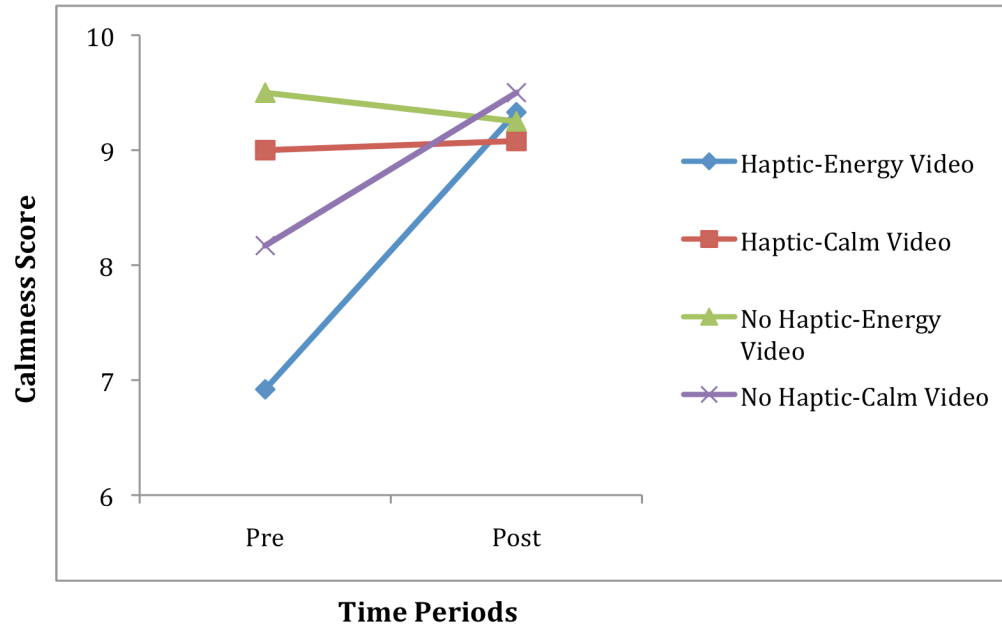


Figure 4. Time x Haptic x Video interaction for calmness measure

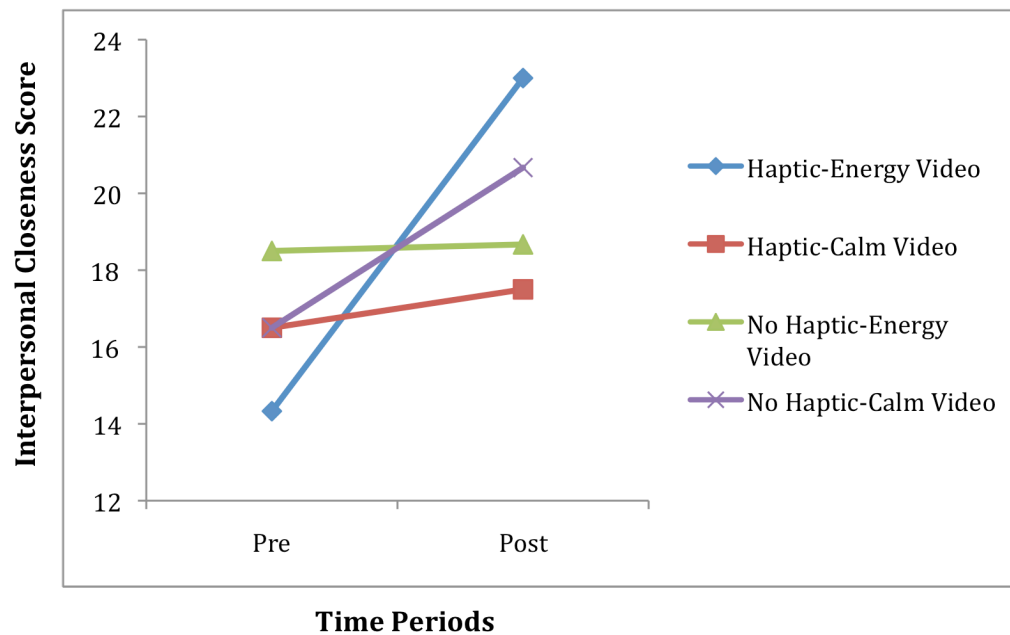


Figure 5. Time x Haptic x Video interaction for interpersonal closeness measure

CHAPTER 5. DISCUSSION

The purpose of this study was to test the effect of watching a video during which participants: (1) either shared or did not share the haptic experience (neck massager) with the actor; and (2) watched the actor convey either energy or calmness. The outcome variables were intended to assess whether the conceptual boundary between self (participant) and other (actor) was blurred, as measured by psychophysiology and self-report of mood and interpersonal closeness to actor. The hypotheses compared to the results are summarized in Table 9.

Table 9

Measures, Hypotheses, and Results

| Measures | Hypotheses | Results |
|-------------------------|---|--|
| Heart rate | Increase with energy video Decrease with calm video (Greater effect in haptic conditions) | Decreased (main effect) |
| Skin conductance | Increase with energy video Decrease with calm video (Greater effect in haptic conditions) | Increased (main effect) |
| Energetic arousal | Increase with energy video Decrease with calm video (Greater effect in haptic conditions) | Decreased (main effect) |
| Calmness | Decrease with energy video Increase with calm video (Greater effect in haptic conditions) | Increased in haptic-energy video (interaction effect) |
| Interpersonal Closeness | Increase in haptic conditions | Increased in haptic-energy video and no haptic-calm video (interaction effect) |

There was a main effect of time for all dependent variables, without regard to haptic device (present versus absent) or video content (energy versus calm). Heart rate decreased, skin conductance increased, self-reported calmness increased, self-reported energetic arousal decreased, and self-reported interpersonal closeness to the actor increased. Additionally, a three-way interaction effect was evident for the measures of calmness and interpersonal closeness.

The following discussion will first address heart rate and skin conductance, followed by calmness and energetic arousal, then interpersonal closeness. Next, limitations and considerations for future studies are addressed, followed by implications for the field of HCI.

Across conditions, there was a significant decrease in heart rate between the pre-period (the five minutes prior to the start of the video) and post-period 1 (the two latter minutes of the video and three minutes following) and post-period 2 (the five minutes following the video). The slight increase from post-period 1 to post-period 2 suggests that heart rate was returning to its baseline (pre) measurement. These results are in contrast to the hypothesis that heart rate would increase in the energy video conditions and decrease in the calm video conditions. Heart rate psychophysiology literature helps elucidate why heart rate decreased even in the presence of an actor showing energy.

A slowing of heart rate generally accompanies presentation of a novel stimulus (Lynn, 1966). Heart rate deceleration has been found to involve the mental intake of environmental stimuli or to accompany situations in which subjects “take in” perceptual materials; decreased heart rate has also been recorded during performance of a task as associated with increased sensitivity to stimulation (Lacey, Kagan, Lacey, & Moss, 1963).

Andreassi (2000, p. 267) stated that “in general, it has been found that heart rate slows and variability decreases during intensive attention to stimuli.” However, if the external stimulus is a source of psychological stress, anxiety, or fear, heart rate will instead increase (Andreassi).

A couple of studies illuminate this dichotomy. In one, children watched three film clips of 70 seconds each while heart rate was monitored. Heart rate accelerated during the anxiety-provoking film, and decelerated in the films meant to induce sadness and sympathy (Eisenberg,

Fabes, Bustamante, Mathy, Miller, & Lindholm, 1988). In another study, participants were shown slides of spiders. The 10 participants who feared spiders had heart rate acceleration, and the 10 who did not had deceleration—especially when they found the slides interesting (Hare, 1973).

Thus, Andreassi (2000) summarized that there is good support for the hypothesis that heart rate deceleration is associated with the orienting response and stimulus intake, and heart rate acceleration is associated with the defensive reaction and stimulus rejection. In the present study, this hypothesis also appears to be supported; neither of the videos, nor the haptic device, would generally be a cause of stress, anxiety, or fear, and therefore the decrease in heart rate can be interpreted as an orienting response and stimulus intake, and perhaps an indication of interest. Although it was hypothesized that the energy video would result in heart rate acceleration, either the video: (1) did not have an accelerating effect on heart rate at all, or (2) the accelerating effect was insufficient to counteract the “novel stimulus” effect on heart rate.

Across conditions, there was a significant increase in mean skin conductance from the pre-period (the five minutes prior to the start of the video) to post-period 1 (the two latter minutes of the video and three minutes following) and post-period 2 (the five minutes following the video). The difference between Post 1 and Post 2 was not significant. These results are in contrast to the hypothesis that skin conductance would only increase in the energy video conditions and only decrease in the calm video conditions. Skin conductance psychophysiology literature helps elucidate why skin conductance increased even in the presence of an actor showing calmness.

Increased skin conductance level generally means increased arousal and/or attention, and a response may be defined as any change of 0.05 umho or greater within a specified time

(Andreassi, 2000). Thus, for example, high arousal words have produced significantly larger skin conductance responses than low arousal words (Maltzman, Kantor, & Langdon, 1966). In short-term memory tasks, optimal performance was associated with the largest increases in skin conductance and heart rate (Yuille, & Hare, 1980). Learning easy materials, as compared to moderately hard or hard learning materials, was shown to result in significantly higher skin conductance level (and heart rate), which was interpreted as greater subject involvement and arousal in the learning task when their performance was more successful (Andreassi, 1966). On the other hand, overlearning (due to stimulus and situational habituation) has been shown to lead to significant decreases in skin conductance level as well as heart rate (Andreassi & Whalen, 1967).

Although it was hypothesized that the calm video would result in a decrease in skin conductance, either the video: (1) did not have a reducing effect on skin conductance at all or (2) the reducing effect was insufficient to counteract the “arousal/attention” effect on skin conductance.

So, for example, although participants practicing transcendental meditation had a decrease in both heart rate and skin conductance level (Wallace & Benson, 1972), this decrease in skin conductance was not found in any of this study’s conditions. The relaxation or calming effect on skin conductance derived from meditation may, then, be associated with closing the eyes (blocking external stimuli) and may not be achievable by attending to external stimuli—even if the stimuli are intended to be relaxing or calming. It is interesting to note, however, that participants did report an increase in calmness (which will be discussed below).

This combination of a decrease in heart rate and increase in skin conductance is not common in the literature, and where it is found, the circumstances are quite variable. Hamrick

(1974), in showing erotic stimuli (i.e., nude males, as compared to flowers) to 52 female undergraduates, found significant increases in skin conductance response and decreases in heart rate, which were accompanied by subjective ratings that indicated sexual arousal and positive affective reactions. In a study on the antecedents and consequences of decision-making with regard to risky choices, heart rate slowed and skin conductance level increased following loss relative to reward outcomes (Crone, Somsen, van Beek, & Van Der Molen, 2004). In another study, both people who stutter and fluent speakers showed similar patterns of response in reacting to stuttered versus fluent speech: skin conductance response was significantly increased and heart rate was significantly decreased (Zhang, Kalinowski, Saltuklaroglu, & Hudock, 2010). Additionally, this “orienting reflex” has been noted in the viewing of television (which has similarities to the viewing of the video in the experiment)—particularly in the rapid-fire expositions that abound in children’s television (Zillmann, 1991b). Therefore, this pattern of response cannot be said to capture a simple or specific categorization of experience.

This author’s prediction that heart rate and skin conductance would rise and fall together was based on the research cited above in the literature review and on postulates of activation theory (e.g., Cannon, 1915). However, criticisms of activation theory can be found in the principal of *stimulus-response specificity*, which states that specific stimulus contexts “...bring about certain patterns of responding, not just an increase or decrease in an unidimensional activation continuum... By definition, a stimulus-response specificity exists if a stimulus brings about a similar pattern of physiological responding among most subjects” (Stern, Ray, & Quigley, 2001, p. 54; p. 65).

Lacey (1967) noted a special case of stimulus-response specificity, which he called directional fractionation and which occurs when response directions are not uniform. Therefore,

for example, a person who is attentive to a potential threat will experience a decrease in heart rate and an increase in skin conductance.

However, this particular physiological response does not necessarily imply stress, but is in fact an orienting response, which enhances our sensory processing while directing our attention to novel stimuli (Stern, Ray, & Quigley, 2001). The function of the orienting response is to help us deal with novel stimuli. Stern, Ray, and Quigley (2001) stated that this response habituates rapidly after stimulus repetition.

Additionally, “We still do not know a great deal about the complex relationship of the central nervous system to EDA [electrodermal activity]” (Stern, Ray, & Quigley, 2001, p. 209). Boucsein (1992) asserted that there are two separate portions of the central nervous system involved in electrodermal activity—the ipsilateral and a contralateral. He proposed that the ipsilateral system is involved when the stimulus is of an emotional or affective nature, and that contralateral system is involved in orienting, cognition, and locomotion.

Finally, the lack of effect of the neck massager on physiological measures was similarly found by Reed and Held (1988) with regard to connective tissue massage. Since numerous case studies have documented the apparent benefits of such massage, they consequently monitored during the massage variables including galvanic skin response and heart rate. However, there were no consistent immediate or long-term effects on the autonomic nervous system in the study’s middle-aged and elderly participants.

Next examined is Wilhelm and Schoebi’s (2007) Short Mood Scale (Appendix B), in particular its two subscales of calmness and energetic arousal. Across conditions, there was a significant increase in calmness and decrease in energetic arousal. Additionally, there was a three-way interaction effect found for the calmness measure, for which further analysis revealed

a significant effect in only one condition, haptic-energy video. These results are in contrast to the hypothesis that the two calm video conditions would increase calmness and that the two energy video conditions would increase energetic arousal.

First, why would calmness increase in the haptic-energy video condition? As evident in Figure 4, the haptic-energy video group had the lowest mean pre-calmness measure of the four groups; a larger number of participants would have presumably eliminated this discrepancy. Regardless, a significant gain was realized for this condition. However, it is unusual that this effect was not also (or only) present in the haptic-calm video condition, and its absence may be due to insufficient power. Ideally a “control” condition of haptic-no video would have been implemented. Certainly, such neck massagers are marketed as relaxing (e.g., Brookstone, 2013), and although there is a dearth of experimental studies regarding their effects, the user generally has an expectation of relaxation or calming.

Second, why would energetic arousal decrease across conditions? One, this effect could be an artifact of the experimental procedure (i.e., the quiet room, generally low levels of stimulation, and the word search task during the measurement of baseline physiological measures).

Two, the orienting response (as identified by the increase in skin conductance and decrease in heart rate) could have impacted self-reported mood. Specifically, participants may have been more aware of their heart rate decelerating rather than their skin conductance increasing. Heart rate is to some extent perceptible and breathing—the physiological process that most directly influences heart rate—can be voluntarily controlled; but voluntary control (or even awareness) of skin conductance is less likely (Andreassi, 2000; Combatalade, 2010; Schachter, 1964).

Three, the experiment's video is similar to watching television, which "... appears to be a most potent means of providing relief from stress" (Zillmann, 1991b, p. 107). One reason for this is that television viewing likely disrupts "... rehearsal processes that would perpetuate states of elevated arousal associated with negative affective experiences" (Zillmann, p. 109).

Four, color that appeared in the video may have been a confounding factor. The actor wore a blue shirt and the background was blue-gray, and people tend to associate certain colors with certain emotional or arousal states. In two studies, Walters, Apter, and Svebak (1982) concluded that there was a systematic tendency for long-wavelength colors like red and orange to induce feelings of high arousal and for short-wavelength colors like violet and blue to induce feelings of low arousal. Similarly, Wexner (1954) found that participants associated blue with the word group "calm, peaceful, serene."

Therefore, the following factors may have influenced the mood self-reports in the direction of decreased energetic arousal across all conditions and increased calmness in one condition: the experimental environment; the most self-evident physiological change (decreased heart rate); the video's similarity to television; and the prominence of the color blue in the video.

The final measure for discussion is that of interpersonal closeness, which was the sum of the Inclusion of Other with Self Scale (2002) IOS scale (Appendix C) and the questions: How connected do you feel with this person? How similar is this person to your self? How close do you feel to this person? and How much do you like this person? (Appendix D). Across conditions there was an increase in interpersonal closeness as well as a three-way interaction effect, which revealed that two conditions showed a significant pre-post increase: haptic-energy video and no haptic-calm video.

It was hypothesized that both haptic conditions would result in an increase in interpersonal closeness. Therefore, this hypothesis was partially supported by the increase in the haptic-energy video condition, which showed the largest mean increase. Although the mean increase in the no haptic-calm video condition was smaller, it was still significant, which is perplexing. One potential issue is that of confounding variables—in this case, that participants' responses are likely in part influenced by the *content* of the videos. For example, in the energy video, the actor says, "It's almost like right after you exercise, and you are in that crazy adrenaline high, it just makes you want to get things done." A participant who has experienced that feeling may feel closer to the actor after hearing this, whereas a participant who has not experienced that feeling would likely not feel closer, and may come to the conclusion that "this person is *not* like me." Such confounding effects should be considered in any future experiments; perhaps the mood of the actor could be expressed via body language rather than verbal content. On the other hand, such individual differences should at least in theory be about equally dispersed among the four conditions. But as mentioned previously, true random assignment may not have been achieved due to an insufficient number of participants.

Another finding to examine is the increase in interpersonal closeness that was found in the haptic-energy video condition but not in the haptic-calm video condition. One possible reason for this is that energetic people may be perceived as more likeable, and likeability is part of the interpersonal closeness measure (Appendix D). For example, in a study of the personality traits of liked people, individuals who described themselves as "energetic/active" and "happy/joyful" were more liked in the sample of college freshman living in dormitories (Wortman & Wood, 2011). Certainly the actor in the energy video was more energetic and

active than in the calm video, and it could also be argued that the energy video conveyed greater happiness and joy than the calm video (see Appendix A).

Likewise, it is possible that the energy video engendered a more positive mood state than the calm video, thus resulting in a higher interpersonal closeness score. Waugh and Fredrickson (2006), in a study of first-year college students, hypothesized that positive emotions broaden people's feelings of self–other overlap in the beginning of a new relationship. They found that with new roommates, positive emotions predicted increased self–other overlap, which was measured with The Inclusion of Other in Self Scale (Aron, Aron, & Smollan, 1992) that was incorporated into the interpersonal closeness measure in the current study.

Additionally, various studies have found that mood can have a profound effect on information processing and judgments, as well as mimicry behaviors. For example, a correlation has been observed between mood and the non–conscious mimicry of a person on television; the more positive an individual's mood state, the more this individual mimicked the behavior of the person on the television (van Baaren, Fockenberg, Holland, Janssen, & van Knippenberg, 2006).

Finally, the increase in interpersonal closeness in some conditions may in part reflect the mere-exposure effect. The general hypothesis, that mere repeated exposure of an individual to a stimulus is a sufficient condition for the enhancement of his or her attitude toward it, has been supported by a variety of experiments (Bornstein, 1989; Zajonc, 1968). This exposure effect has been found not only for inanimate objects but also for interpersonal attitudes (Saegert, Swap, & Zajonc, 1973). Therefore, it may be that “mere exposure” to the actor (the video) that occurred between the pre- and post- interpersonal closeness measurement impacted the scores.

The most salient finding of this study was the significant pre-post gain in interpersonal closeness in the haptic-energy video condition. The haptic effect was hypothesized, and possible

reasons for the energetic condition interaction were addressed above. HCI applications that contain both haptic and interpersonal closeness factors would be wise to consider this effect and subject them to further testing. With regard to the hypothesized (but unrealized) effect of the haptic factor blurring mood (i.e., increasing emotional contagion) between participant and actor, it is possible that the “experiential match” (the neck massager) between the actor and the participant was too subtle. Future studies may want to consider this. The relevant literature emphasizes “action” (e.g., Preston & de Waal, 2002; Rizzolatti et al., 1996; Semin & Cacioppo, 2008) and thus the passive haptic match between participant and actor (without movement) may not have been sufficient to invoke the hypothesized effects. On the other hand, mood was not a factor in the studies on synchronous stimulation and conceptual boundaries (e.g., Mazzurega et al.; 2011, Paladino et al., 2010; Sforza et al., 2008) and therefore may not be susceptible to the manipulations performed in the present experiment. Additionally, the results may point to possible important differences between human-to-human versus human-to-screen interactions.

The increase in interpersonal closeness that was found in the haptic-energy video condition has a number of potential applications in HCI – for example, in the areas of user experience and mental health therapy. With regard to user experience, as discussed in the literature review the tactile illusion induced by the rubber hand illusion can be used in a virtual environment to induce the feeling of inhabiting a different body (as presented via a first-person perspective using immersive technology). Similarly, Meehan, Insko, Whitton, and Brooks (2002) found that inclusion of a passive haptic element in a virtual environment significantly increased presence – a sense of being in the virtual, as opposed to the real, environment. Less explored is the notion of increasing presence or engagement in a low-immersion environment and with a “third-person” perspective. In other words, if a user’s avatar in a two-dimensional

display experiences a haptic event, and the user simultaneously experiences that haptic event via a controller or a vest, will that improve user experience? With regard to video games, such haptic feedback is related to an increased sensation of presence (Tamborini & Skalski, 2006). The current study's contribution to extending this finding is that, if an interaction designer sought to increase a user's feelings of interpersonal closeness to an actor, avatar, or virtual agent, synchronous haptic experience may indeed prove beneficial. Important factors for exploration in future research include levels of immersion and levels of interaction. It may be that even in a low-immersion, low-interaction experience such as a movie, a shared haptic experience may contribute to an improved experience.

In terms of therapeutic benefits, Vaucelle, Bonanni, and Ishii (2009) summarized that touch is essential to our well-being, and that medical science is consequently developing therapies to incorporate haptics into the treatment of conditions such as autism spectrum, mood, anxiety and borderline disorders. They described that autistic patients respond to application of weighted vests and blankets, which prevent or ameliorate crisis states or panic attacks. Perhaps modifying this intervention with an HCI element of a synchronous haptic experience as used in the current study would make this intervention more effective. Results of the current study suggest that a synchronous haptic experience with an energetic person in a video (which perhaps may be generalized to an avatar or a virtual agent) increases feelings of interpersonal closeness while also increasing feelings of calmness. If an increase in interpersonal closeness (or perhaps empathy) as well as calmness were goals of a given therapy, then such synchronous haptic experience may be an appropriate piece of the interaction design of a novel HCI-based therapy. More specifically, given that autism has been associated with dysfunction in the mirror neuron system (e.g., Perkins, Stokes, McGillivray, & Bittar, 2010), and given the possible role of the

mirror neuron system in this study (as discussed in the literature review), this is a potential area for research.

Furthermore, Vaucelle, Bonanni, and Ishii (2009) related that a number of computer-mediated therapies are showing promise in the treatment of mental problems because of such therapies' capacity to enrich patient-therapist collaboration. In this vein, they have prototyped haptic devices, such as "Touch Me" and "Squeeze Me," based on existing touch therapy protocols and the availability of robust haptic technologies. Such devices, they explained, may augment patient-therapist connection. What they do not address, but what is suggested by the current study, is that there may be benefits to the patient-therapist connection if the therapist were to simultaneously experience the haptic experience along with the patient. Such devices are not meant to replace human touch, but are a way to offer patients some of the benefits of touch "on a personalized basis without the risks associated with direct touch" (Vaucelle et al., p. 468). Additionally, they explained that (for example) sensory defensive patients can be overwhelmed by human contact, and thus such devices can be an important alternative. Although these authors do not explore the possibilities of pairing a haptic device with a computer mediation or video intervention (in a manner similar in the current study), that is certainly a possible avenue of future investigation.

This study had a number of limitations. The sample size for each of the four conditions ($n=12$) was relatively small, and a larger sample size would have resulted in greater power and may have led to the discernment of further effects. The use of male participants (with a male actor) may have revealed different results than the all-female participant pool. Although a few participants were of a different race or ethnicity than the actor, the sample was not large enough

to ascertain whether these differences affected the outcomes. Finally, at three minutes, the video intervention was somewhat brief and may have produced different results if it was longer.

An additional limitation is that the post time periods as defined included the activity of completing the post-questionnaires. Although this was a relatively short process (about one minute of the five minutes from which the mean was derived), future studies may want to use time periods that end at the conclusion of the intervention, or that do not include post-questionnaire tasks.

The study brought to light some additional measures that could be considered in future research. For example, one participant in the haptic-energy condition commented that she felt the intervention created an improvement in her performance on the word search. The word search was used as a neutral activity to pass time during physiological recording, but it (or a similar activity) could in fact be used to assess whether there is a change in pre-post task performance among the different conditions.

Additionally, it might be interesting to assess participants' individual differences in susceptibility to emotional contagion. Doherty (1997) developed the Emotional Contagion Scale, which measured susceptibility to other's emotions (resulting from afferent feedback generated by mimicry). He found that such susceptibility was: (1) positively related to reactivity, emotionality, sensitivity to others, social functioning, and self-esteem; and (2) negatively related to alienation, self-assertiveness, and emotional stability. Therefore, in similar future studies, examining the role of participants' susceptibility to emotional contagion could offer further insights.

In a broader sense, this study was important in taking the metaphoric "overlap" between self and other (which is well-covered in the literature) and bringing it into the experimental

realm. The study herein was based on theoretical evidence that this metaphor is grounded in the body (i.e., that sensorimotor inference informs concepts and social cognition, Lakoff & Johnson, 1999; Schubert & Koole, 2009; Semin & Smith, 2008; Smith, 2008). Additionally, these theories have been supported by studies that have demonstrated that simple body-based manipulations (e.g., of facial expression, posture, or movement) can causally influence the processing of emotional information (Winkielman et al., 2009) and that the cognitive phenomenon of self-other overlap can arise from a purely sensorial experience (Paladino et al., 2010). Given this evidence that cognitive representations are not amodal but connected with our bodies, the experiment tested manipulations of the sensorimotor domain within a socially-situated human computer interaction. The results shed light on theory, practice, and future directions, as discussed above.

Theories of embodied and situated cognition (in which cognition is seen as taking place not only in the brain, but also in interaction with the world supported by the body) will be central for developments in HCI as well as in related fields such as artificial intelligence (Garg, 2012). Jaimes (2007) observed that the single most widespread topic of the artificial intelligence community is likely to become multimodal context-sensitive human computer interaction involving emotional inference. There is already a vast body of literature on emotion *recognition* in affective computing (Jaimes, 2007), but once emotion is recognized, the question still remains: what do we do with it? Future work must seek to understand the affective feedback loop between the user and the computer system. To build intelligent, adaptive systems, we need a deep comprehension not only of the computer system, but of the human system as well. As HCI progresses from information design to experience design, from inelegant artifacts to ambient

intelligence, we must strive to understand the interaction of technology and the body, affect, and social cognition:

We think of social and group experiences based on communicating closeness, connectedness, awareness, interaction, and—at a higher level—perhaps even friendship. The task of experience design is now to identify the relevant parameters for a given situation, collect their corresponding raw data, aggregate them—if necessary—at a defined level and in some cases map them to an intermediate representation which is then used for the final mapping to output/display parameters on the different dimensions that are accessible to the human senses. This implies defining certain codes sometimes involving metaphors that tap the everyday background knowledge and experiences of people. (Streitz, Magerkurth, Prante, & Rucker, 2005, p. 23)

An embodied, embedded social psychology serves this end; it helps us challenge the normal way of thinking and takes rather seriously that “... causality resides at the level of the interaction, rather than in our head” (Marsh et al., 2009, p. 1220).

In summary, this thesis first examined how the boundaries of the self, both physical and conceptual, may be manipulated to incorporate external objects (in the physical sense) and other people (in the conceptual sense). Implications for HCI were also considered. It was noted that although the literature offers many discussions of the metaphoric overlap between self and other, experimental study of the embodied aspects of this phenomenon has been lacking.

Second, then, this thesis produced an experiment that manipulated factors potentially involved in self-other overlap in an HCI context. The results suggested that heart rate, skin conductance, and energetic arousal were affected by the presentation of a video, but were not

affected by the content of the video or the presence/absence of a haptic match with the actor.

Thus, the synchronous haptic experience did not seem to impact measures of emotional contagion.

However, interpersonal closeness overall increased, with the greatest increase occurring in the haptic-energy video condition—a finding deserving further exploration. The pairing of a shared haptic experience with an energetic “other” may increase feelings of interpersonal closeness as well as calmness. These kinds of empirical findings coupled with advances in HCI present new directions in blurring the boundary between the user and the interface. Such an embodied approach will likely prove valuable not only for refining human computer interaction, but for understanding the user as well.

APPENDIX A

Video Scripts

In both videos, the actor is seated facing the camera, wearing the neck massager. The investigator instructs, “OK, I’m going to turn this [neck massager] on, just talk about how it makes you feel over the next couple minutes.” The actor improvised according to prescribed guidelines. These are the transcriptions:

Energizing Video Script (EV) [fidgeting, upright]:

Gosh, I feel like this is giving me energy.

It’s almost like right after you exercise, and you are in that crazy adrenaline high, it just makes you want to get things done.

I should just stop spending money on coffee and just get this for the mornings, that’s what I should do.

I just, I feel so much more alert than what I usually am, especially in the mornings.

I’m definitely feeling a lot more awake than when I sat down, that’s for sure.

I’m going to get so much done after this.

Calming Video Script (CV) [yawning, sinking in chair]:

I feel like this is calming me down.

This just makes me want to forget about everything I had to get done today.

This would be really great to maybe use at night before bedtime.

I feel so much more relaxed than when I sat down.

It seems a little chilly in here.

I wonder if this is designed to make you feel really sleepy.

This is better than my herbal tea before bed.

It’s so soothing.

APPENDIX B**Short Mood Scale (Wilhelm & Schoebi, 2007)**

At this moment I feel:

VERY

VERY

1. Tired

Awake

| | | | | | | |
|---|---|---|---|---|---|---|
| 0 | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|

2. Content

Discontent

| | | | | | | |
|---|---|---|---|---|---|---|
| 0 | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|

3. Agitated

Calm

| | | | | | | |
|---|---|---|---|---|---|---|
| 0 | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|

4. Full of energy

Without energy

| | | | | | | |
|---|---|---|---|---|---|---|
| 0 | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|

5. Unwell

Well

| | | | | | | |
|---|---|---|---|---|---|---|
| 0 | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|

6. Relaxed

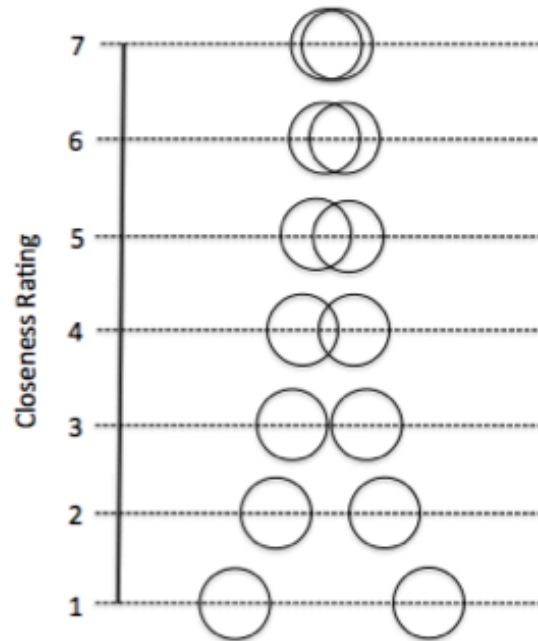
Tense

| | | | | | | |
|---|---|---|---|---|---|---|
| 0 | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|

APPENDIX C

Paladino et al. (2010)'s version of Schubert and Otten (2002)'s Inclusion of Other in Self Scale (originally developed by Aron, Aron, and Smollan, 1992)

Circle the number that best represents your relation to the person on the video screen (1 is most distant; 7 is most close)



APPENDIX D

Interpersonal Closeness Questions

Please circle one number for each item regarding the person on the video screen:

1. How connected do you feel with this person?

| | | | | | | | | |
|------------|---|---|---|---|---|---|---|-----------|
| NOT AT ALL | | | | | | | | VERY MUCH |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |

2. How similar is this person to your self?

| | | | | | | | | |
|------------|---|---|---|---|---|---|---|-----------|
| NOT AT ALL | | | | | | | | VERY MUCH |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |

3. How close do you feel to this person?

| | | | | | | | | |
|------------|---|---|---|---|---|---|---|-----------|
| NOT AT ALL | | | | | | | | VERY MUCH |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |

4. How much do you like this person?

| | | | | | | | | |
|------------|---|---|---|---|---|---|---|-----------|
| NOT AT ALL | | | | | | | | VERY MUCH |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |

APPENDIX E

IOWA STATE UNIVERSITY
OF SCIENCE AND TECHNOLOGY

Institutional Review Board
Office for Responsible Research
Vice President for Research
1138 Pearson Hall
Ames, Iowa 50011-2207
515 294-4566
FAX 515 294-4267

Date: 10/8/2012

To: Norene Kelly
1620 Howe Hall

CC: Dr. Peter Martin
1085 Elm Hall

From: Office for Responsible Research

Title: Consequences of shared haptic experience on self-other boundaries

IRB ID: 12-447

Approval Date: 10/5/2012 **Date for Continuing Review:** 10/4/2014

Submission Type: New **Review Type:** Expedited

The project referenced above has received approval from the Institutional Review Board (IRB) at Iowa State University according to the dates shown above. Please refer to the IRB ID number shown above in all correspondence regarding this study.

To ensure compliance with federal regulations (45 CFR 46 & 21 CFR 56), please be sure to:

- Use only the approved study materials in your research, including the recruitment materials and informed consent documents that have the IRB approval stamp.
- Retain signed informed consent documents for 3 years after the close of the study, when documented consent is required.
- Obtain IRB approval prior to implementing any changes to the study by submitting a Modification Form for Non-Exempt Research or Amendment for Personnel Changes form, as necessary.
- Immediately inform the IRB of (1) all serious and/or unexpected adverse experiences involving risks to subjects or others; and (2) any other unanticipated problems involving risks to subjects or others.
- Stop all research activity if IRB approval lapses, unless continuation is necessary to prevent harm to research participants. Research activity can resume once IRB approval is reestablished.
- Complete a new continuing review form at least three to four weeks prior to the date for continuing review as noted above to provide sufficient time for the IRB to review and approve continuation of the study. We will send a courtesy reminder as this date approaches.

Please be aware that IRB approval means that you have met the requirements of federal regulations and ISU policies governing human subjects research. **Approval from other entities may also be needed.** For example, access to data from private records (e.g. student, medical, or employment records, etc.) that are protected by FERPA, HIPAA, or other confidentiality policies requires permission from the holders of those records. Similarly, for research conducted in institutions other than ISU (e.g., schools, other colleges or universities, medical facilities, companies, etc.), investigators must obtain permission from the institution(s) as required by their policies. IRB approval in no way implies or guarantees that permission from these other entities will be granted.

Upon completion of the project, please submit a Project Closure Form to the Office for Responsible Research, 1138 Pearson Hall, to officially close the project.

Please don't hesitate to contact us if you have questions or concerns at 515-294-4566 or IRB@iastate.edu.

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